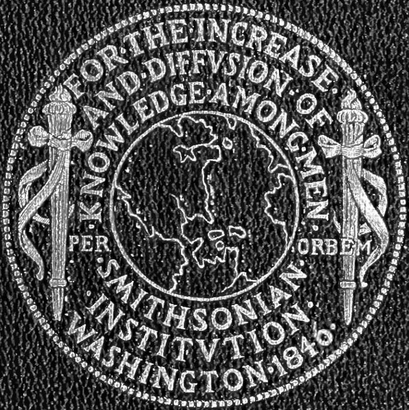
FOR THE INCREASE AND DIFFVSION OF KNOWLEDGE AMONG MEN
PER ORBEM
SMITHSONIAN INSTITVTION
WASHINGTON 1846

ANNUAL REPORT

OF THE

BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION,

SHOWING

THE OPERATIONS, EXPENDITURES, AND CONDITION
OF THE INSTITUTION

FOR

THE YEAR ENDING JUNE 30, 1900.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1901.

LETTER

FROM THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

ACCOMPANYING

The Annual Report of the Board of Regents of the Institution for the year ending June 30, 1900.

SMITHSONIAN INSTITUTION,
Washington, D. C., March 1, 1901.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the Annual Report of the operations, expenditures, and condition of the Smithsonian Institution for the year ending June 30, 1900.

I have the honor to be, very respectfully, your obedient servant,

S. P. LANGLEY,
Secretary of Smithsonian Institution.

Hon. WILLIAM P. FRYE,
President pro tempore of the Senate.

ANNUAL REPORT OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDING JUNE 30, 1900.

SUBJECTS.

1. Proceedings of the Board of Regents for the session of January, 24, 1900.

2. Report of the executive committee, exhibiting the financial affairs of the Institution, including a statement of the Smithson fund, and receipts and expenditures for the year ending June 30, 1900.

3. Annual report of the Secretary, giving an account of the operations and condition of the Institution for the year ending June 30, 1900, with statistics of exchanges, etc.

4. General appendix, comprising a selection of miscellaneous memoirs of interest to collaborators and correspondents of the Institution, teachers, and others engaged in the promotion of knowledge. These memoirs relate chiefly to the calendar year 1900.

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THE SMITHSONIAN INSTITUTION.

MEMBERS EX OFFICIO OF THE "ESTABLISHMENT."

William McKinley, President of the United States.
Garret A. Hobart, Vice-President of the United States.[1]
Melville W. Fuller, Chief Justice of the United States.
John Hay, Secretary of State.
Lyman J. Gage, Secretary of the Treasury.
Russell A. Alger, Secretary of War, to July 31, 1899.
Elihu Root, Secretary of War, from August 1, 1899.
John W. Griggs, Attorney-General.
Charles Emory Smith, Postmaster-General.
John D. Long, Secretary of the Navy.
E. A. Hitchcock, Secretary of the Interior.
James Wilson, Secretary of Agriculture.

REGENTS OF THE INSTITUTION.

(List given on the following page.)

OFFICERS OF THE INSTITUTION.

Samuel P. Langley, *Secretary,*

Director of the Institution and of the U. S. National Museum.

Richard Rathbun, *Assistant Secretary.*

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[1] Died November 21, 1899.

REGENTS OF THE SMITHSONIAN INSTITUTION.

By the organizing act approved August 10, 1846 (Revised Statutes, Title LXXIII, section 5580), "The business of the Institution shall be conducted at the city of Washington by a Board of Regents, named the Regents of the Smithsonian Institution, to be composed of the Vice-President, the Chief Justice of the United States, three members of the Senate, and three members of the House of Representatives, together with six other persons, other than members of Congress, two of whom shall be resident in the city of Washington and the other four shall be inhabitants of some State, but no two of the same State.

REGENTS FOR THE YEAR ENDING JUNE 30, 1900.

The Chief Justice of the United States:
MELVILLE W. FULLER, elected Chancellor and President of the Board, January 9, 1889.

The Vice-President of the United States:
GARRET A. HOBART (March 4, 1897). Died November 21, 1899.

	Term expires.
United States Senators:	
SHELBY M. CULLOM (appointed Mar. 24, 1885, Mar. 28, 1889, and Dec. 18, 1895)	Mar. 3, 1901
ORVILLE H. PLATT (appointed Jan. 18, 1899)	Jan. 18, 1905
WILLIAM LINDSAY (appointed Mar. 3, 1899)	Mar. 3, 1905
Members of the House of Representatives:	
JOSEPH WHEELER (appointed Jan. 10, 1888, Jan. 6, 1890, Jan. 15, 1892, Jan. 4, 1894, Dec. 20, 1895, and Dec. 22, 1897)	Dec. 22, 1899
ROBERT R. HITT (appointed Aug. 11, 1893, Jan. 4, 1894, Dec. 20, 1895, Dec. 22, 1897, and Jan. 4, 1900)	Dec. 25, 1901
ROBERT ADAMS, Jr. (appointed Dec. 20, 1895, Dec. 22, 1897, and Jan. 4, 1900)	Dec. 25, 1901
HUGH A. DINSMORE (appointed Jan. 4, 1900)	Dec. 25, 1901
Citizens of a State:	
JAMES B. ANGELL, of Michigan (appointed Jan. 19, 1887, Jan. 9, 1893, and Jan. 24, 1899)	Jan. 24, 1905
ANDREW D. WHITE, of New York (appointed Feb. 15, 1888, Mar. 19, 1894, and June 2, 1900)	June 2, 1906
WILLIAM PRESTON JOHNSTON, of Louisiana (appointed Jan. 26, 1892, and Jan. 24, 1898), died July 16, 1899.	
RICHARD OLNEY (appointed Jan. 24, 1900)	Jan. 24, 1906
Citizens of Washington:	
JOHN B. HENDERSON (appointed Jan. 26, 1892, and Jan. 24, 1898)	Jan. 24, 1904
WILLIAM L. WILSON (appointed Jan. 14, 1896)	Jan. 14, 1902
ALEXANDER GRAHAM BELL (appointed Jan. 24 1898)	Jan. 24, 1904

Executive Committee of the Board of Regents.

J. B. Henderson, *Chairman*.
William L. Wilson.
Alexander Graham Bell.

PROCEEDINGS OF THE BOARD OF REGENTS

At the Annual Meeting, January 24, 1900.

In accordance with the resolution of the Board of Regents, adopted January 8, 1890, by which its stated annual meeting occurs on the fourth Wednesday of January, the Board met to-day at 10 o'clock a. m.

Present: The Chancellor (Mr. Chief Justice Fuller), in the chair; the Hon. W. P. Frye, President pro tempore of the Senate, who was present by invitation of the Regents in place of the late Vice-President Hobart; the Hon. S. M. Cullom, the Hon. O. H. Platt, the Hon. R. R. Hitt, the Hon. Robert Adams, jr., the Hon. Hugh A. Dinsmore, Dr. James B. Angell, the Hon. J. B. Henderson, Dr. Alexander Graham Bell, and the Secretary, Mr. S. P. Langley.

The Secretary said that while he had no excuses for non-attendance to read he might state that Dr. Wilson had left so recently for Arizona that there had been scarcely time to hear from him, and that the appointment of Mr. Richard Olney as a Regent by joint resolution of Congress was still awaiting the President's signature.

At the Chancellor's suggestion, the Secretary read the minutes of the last annual meeting in abstract, and there being no objection the minutes were declared approved.

The Secretary announced the death of Dr. William Preston Johnston, a Regent of the Institution, with a few remarks, and, at the request of the Chancellor, Dr. Angell submitted a minute and resolutions, which will be found under the heading "Necrology," on page 47 of the report of the Secretary.

On motion, the minute and resolutions were adopted by a rising vote, with the provision that they be suitably engrossed and transmitted to the family of Dr. Johnston.

The death was announced of Vice-President Garret A. Hobart, a Regent of the Institution, and Senator Platt was designated to submit a minute and resolutions. These will be found under the heading "Necrology," on page 49 of the Secretary's Report.

On motion, the minute and resolutions were adopted by a rising vote, with the provision that they be suitably engrossed and transmitted to the family of Vice-President Hobart.

The Secretary then read a letter from Mr. James S. Morrill, returning his thanks to the Regents for the resolutions concerning Senator Morrill, his father, passed by the Regents at their last meeting.

The Secretary then announced the appointment of the following Regents:

Senator William P. Frye, President pro tempore of the Senate, requested to be present in the place of the Vice-President, deceased.

Senator William Lindsay, appointed March 3, 1899, to succeed Senator George Gray.

Representative R. R. Hitt, appointed January 4, 1900, to succeed himself.

Representative Robert Adams, jr., appointed January 4, 1900, to succeed himself.

Representative Hugh A. Dinsmore, appointed January 4, 1900, to succeed Representative Joseph Wheeler.

The Secretary then presented his annual report to June 30, 1899, stating that customarily the Secretary made a personal and viva voce report in a manner which enabled the Regents to question him on any points on which they wished information, but that now, by the advice of the Chancellor, as there would probably be scarcely time for later special business, he would do little more than refer the members to his printed report, which they had already received.

He then spoke of the fact that while the Institution was never so well known abroad or more honored than now the enormous increase of endowments of most institutions of learning in this country left it with relatively far less means than it once had. With the exception of $200,000 from Mr. Hodgkins its fund was now practically what it was fifty years ago, and he urged that its future independence and usefulness were concerned in its being able in some way to command such added means as would leave the Regents with a free disposition of a larger fund than at present and one absolutely under their own control. He had intended to ask the Board to use part of the time at their disposal at this meeting in discussing the question and in advising him as to their wishes upon this point, which he had thought better not to enlarge upon in his printed report. Under the circumstances he would not press the matter now, but he hoped that what he said might receive the consideration of the Regents as a part of his report.

On motion the Secretary's report was accepted.

Senator Henderson then presented the report of the Executive Committee to June 30, 1899, which, on motion, was adopted.

Senator Henderson then presented the customary resolution relative to income and expenditure, as follows:

Resolved, That the income of the Institution for the fiscal year ending June 30, 1901, be appropriated for the service of the Institution, to be expended by the Secretary with the advice of the Executive Committee, with full discretion on the part of the Secretary as to items.

On motion the resolution was adopted.

Senator Henderson, chairman of the Permanent Committee, then reported upon the condition of the Hodgkins and Avery estates, stating that there remained in the hands of the executor of Mr. Hodgkins's will the sum of nearly $9,000, which would have been paid over some time before to the Institution but for the fact that notice had been served on the executor to retain money sufficient to meet possible litigation.

Senator Henderson also referred to the conditional bequest of Wallace C. Andrews, who died in April, 1899, and who, after disposing of half a million dollars of his large property, gave the residue of his estate to trustees for the purpose of establishing an institution for the free education of girls, stating at the close of his will that in case his intention with respect to the institution for girls "shall, because of illegality, become impossible of realization, I then devise and bequeath the sum intended for it to the Smithsonian Institution at Washington, D. C., to be devoted for the purpose for which it was established."

The terms of this will had been studied, with a view of ascertaining whether the gift was valid under the laws of New York, with special reference to perpetuity. As yet no defect had been discovered. The will had been drawn with great care, evidently by some one thoroughly cognizant with the law.

If Mr. Andrews's estate were a little more than $500,000, the surplus would not suffice to carry out the plan of the institution for girls. In that event, this surplus would come to the Smithsonian Institution. As yet, the permanent committee had not been informed how large the estate was.

KIDDER BEQUEST.

The Secretary stated that he would like to bring before the attention of the Board, briefly, the matter of the Kidder Bequest of $5,000. This bequest had already been placed on the same footing by the Board with a similar sum given as a donation by Dr. Alexander Graham Bell, both being put at the disposal of the Secretary. Dr. Bell was here and able to explain the meaning of his gift, but Dr. Kidder was so no longer, and the Secretary felt a scruple about using this money for scientific researches in which he might be the principal agent without being sure that the Regents understood exactly the conditions in question.

In order that there should be a thorough understanding about the matter, he would ask Dr. Bell to make a statement of the facts.

Dr. Bell said that previous to the appointment of Mr. Langley as Secretary, Professor Baird had been afraid that the Secretary of the Smithsonian might become a purely administrative officer, without time or means for scientific investigation, and Secretary Langley had, in fact, declined to accept the position if he were wholly inhibited from carrying on original researches. After conference, Dr. Kidder and himself (Dr. Bell) had agreed then, at the suggestion of Dr. Baird, to place a certain sum of money at the present Secretary's disposal for scientific investigations. The amount which he (Dr. Bell) gave had been given by him to be devoted for any purpose to which Secretary Langley might wish to put it in his reseaches, and he felt sure that such use would be entirely consonant with the wish of Dr. Kidder.

Dr. Bell then offered the following resolution:

> Whereas, at the meeting of the Board of Regents held January 27, 1892, the following resolution was passed:
>
> "That Congress having appropriated $10,000 for the maintenance of an astrophysical observatory, without reference to any precedent condition of buildings to be furnished by the Smithsonian Institution, that the Secretary be authorized to expend, under the general resolution relative to income and expenditure, the sum of $5,000 bequeathed by Dr. J. H. Kidder, and $5,000 given by Alexander Graham Bell, in directions consonant with the known wishes of the testator and the donor."
>
> *Resolved*, That to prevent any misconception as to the meaning of this resolution the Board of Regents declare that it was their intent that the sum of $5,000, received from the estate of Dr. J .H. Kidder, be placed at the disposal of the Secretary for his personal scientific investigations.

After some further discussion, on motion the resolution was adopted.

THE SECRETARY'S STATEMENT.

The Secretary then said that, owing to the evident limitations of time at the Board's disposal, he would abridge his usual statement to it.

He spoke briefly of the National Museum, of the cooperation of the State, War, and Navy Departments in providing animals for the National Zoological Park, and of the relationship of the Institution to the Board of Ordnance and Fortifications.

In regard to this last he said that it was a matter on which he would state to the Regents that his connection with experiments, which had already their sanction, was being continued on the request of the War Department, and reminded them that it was estimated that these experiments would occupy, even if crowned with unexpectedly early success, two or more years. The sum allotted by the War Department would be insufficient to carry out this work were it not for the permission of the Regents already given to make use of the facilities in the workshops under their control, though at the cost of the War Department. The Secretary was giving his time in his private hours, apart from his official duties, to this work, and without charge.

The Secretary then spoke of the Hodgkins Fund, of the awarding of the medal to Prof. James Dewar, of the coming solar eclipse of May 28, 1900, and of the probability of an appropriation by Congress for this purpose.

In regard to the civil service the Secretary said:

The Board will remember that at its meeting held in 1898 the Regents passed a resolution instructing the Secretary to request of the President certain modifications in the civil-service regulations, and at its meeting last year the Board was informed that the Chancellor, together with the Secretary, had called upon the President, who stated that he was holding the matter under advisement. As a result of this action, I beg to report that in the President's order of May 29, 1899, directing certain modifications and additions to the civil-service rules, the position of assistant secretary of the Smithsonian Institution in charge of the National Museum and one private secretary or confidential clerk to the Secretary of the Institution were relieved from examination; that for positions on the scientific staff of the Institution noncompetitive examinations are permitted, or examinations may even be waived, provided the President approve of such action in each case, persons thus entering the service being not eligible to transfer to other divisions of the classified service.

Continuing his statement the Secretary briefly mentioned the subjects of the National Reserves, the International Catalogue of Scientific Literature, and the Centennial Celebration of Professor Henry's birth, as well as the relinquishment of the Toner Lecture Fund.

The Secretary then called attention to a second gift to the Institution from the late Chinese minister, Chang Yen Hoon, of an interesting bronze piece of great antiquity, which was shown to the Regents. On motion, the Secretary was requested to make a proper acknowledgment "by direction of the Board."

NATIONAL UNIVERSITY.

Senator Henderson then presented the following report of the Special Committee:

WASHINGTON, D. C., *January 24, 1900.*

To the Board of Regents:

In July, 1897, a meeting of the American Association of Agricultural Colleges and Experiment Stations was held in Minneapolis, Minnesota, at which meeting the following resolution was adopted:

"*Resolved,* That a committee of five be appointed by the President to investigate, to consider, and, if practicable, devise a plan whereby graduate students of the land-grant and other colleges may have access to, and the use of, the Congressional Library and the collections in the Smithsonian Institution, the National Museum, and the scientific bureaus of the various departments at Washington of the United States Government, for the purposes of study and research; said plan to include suggestions as to the manner in which such work may be organized, coordinated, and directed to the best advantage; the composition and organization of such a staff as may be necessary to properly coordinate and direct such work, and also an outline of such legislation as may be necessary to effect the general purposes of this resolution."

This committee seems to have made diligent inquiries into the subjects submitted to its investigation, and in the autumn of 1898 presented a full and interesting report of its labors to the Association.

A brief extract from that report is as follows:

"The inquiries and investigations so far made lead the committee to the conclusion that it is entirely practicable to provide for the use of the Library of Congress and the collections of the Smithsonian Institution, the National Museum, and of the various scientific and other bureaus in the several departments of the General Government, by graduate students of the land-grant and other colleges for study and research, and that it is also practicable to organize, coordinate, and direct such work as to make it eminently effective.

"The committee has been greatly desirous that some existing agency be found to undertake such work of organization, coordination, and direction, and has naturally turned to the Smithsonian Institution as the one best fitted for the purpose.

"Each of its great secretaries—Henry, Baird, and Langley—in the language of President Gilman, 'has been free and has felt free to open new roads and enter fresh fields when the public good required it.'

"The permanence of its organization, its objects, and purposes, as expressed in the will of its founder, viz, 'the increase and diffusion of knowledge among men;' the fact that it has nobly performed and is still nobly performing many of the functions incident to the proposed scheme of graduate study and research, by the encouragement of investigation and research, the study of local history and archæology, and the founding of libraries and museums; its broad catholicity and its freedom from partisan influences, have led the committee to hope that it might feel free to take the work in hand.

"It already has all the officers and agents for its successful general control, and to them could wisely be left the selection of such additional officers and agents as might be necessary to direct the details of successful administration. It could wisely control and direct the application of all funds appropriated or donated for its support.

"The committee has thought that, perhaps, the Secretary and Regents might not look favorably upon the idea of constituting the Smithsonian the permanent agent for the control and direction of such graduate work, but that they might be willing to take the initiative in its organization and direction, and when a successful plan was fully developed, might generously relinquish its control to a separate and independent management, such as experience might suggest to be more wise and effective, as it did under Henry in the case of the Weather Bureau, under Baird in the cases of the National Museum, the Fish Commission, and the Bureau of Ethnology, and as it has done under Langley in the cases of the Astrophysical Observatory and the National Zoological Park.

"Any positive recommendation as to the agency for the organization, coordination, and direction of the proposed graduate work, and any detailed plan of organization, are therefore held in abeyance.

"The committee is unable, at the present time, to present a complete outline of the legislation necessary to effect the general purposes of the resolution.

"It submits tentatively, however, that Congress might be asked to provide for the establishment of an administrative office in Washington, preferably in the Smithsonian Institution, in which graduate students of the institutions we represent, and others as well, might be enrolled and directed to the appropriate department.

"To maintain this office, pay the expenses of administration, support graduate courses of research, freely open to the graduate students of the land-grant and other colleges without distinction, sex, or color, on such terms as the administrative office should prescribe, and to aid such students in their researches, Congress might be asked to make an appropriation of, say, $25,000, to be increased annually $1,000, to be expended under the discretion of the institution or department in which the office of administration may be located."

It appears that this report of its committee was unanimously adopted by the Association, and its secretary, Mr. MacLean, under date of December 16, 1898, communicated to Mr. Langley, as Secretary of the Smithsonian Institution, a full report of the proceedings of the Association on the subject. A short extract from Mr. MacLean's letter will best explain the object and purpose of the communication. It is as follows:

"The committee have resolved respectfully to ask you and through you the Regents of the Smithsonian Institution to consider the action of the Association, and in particular, the matter of the report on pages XVIII, XIX.

"The committee further earnestly request you and the Regents of the Smithsonian to intimate to us if the Institution would accede to what is the first preference of all the educators who have been consulted—the establishment of an administrative office in the hands of the Regents and Secretary of the Smithsonian Institution. If the Regents will consider the proposition, the committee would like to have the Regents exercise full power as to the entire plans for the organization of said administrative office. In case of favorable consideration, the committee would be glad to know what steps the committee should take further. It is desired to introduce a bill before the close of the present session of Congress for the authority and petty funds needed in the organization of the work. The committee would be glad to answer any inquiries that you or the Regents would like to make. It is believed that the scope of the work is set forth in the report.

"The committee regret to trouble you among the multifarious affairs ever waiting upon you, but they feel confident that you and the Regents have an interest in the matter so important for education and the diffusion of knowledge as that proposed by the representative and National Association for whom the committee speak.

"Would it be too much to ask if, in your first acknowledgment of the receipt of the document submitted, you will let me know when the Regents are likely to consider the subject? The committee heartily hope for a favorable consideration and are sensible of the grace begged of yourself and the Regents."

This letter of Mr. MacLean, with the accompanying papers, was, at its last January meeting, laid before the Board of Regents by Secretary Langley; whereupon the papers were referred by the Board to a committee of five of its members under direction of the following resolution:

"*Resolved*, That the communication from the committee representing the agricultural colleges of the United States be referred to a committee of Regents to be appointed by the Chancellor, to consider the same and all kindred questions, and to make a report thereon at the next meeting of the Board."

The Chancellor appointed the Executive Committee consisting of J. B. Henderson, William L. Wilson, and Alexander Graham Bell, and also J. B. Angell and R. R. Hitt. The Secretary, at his own request, was not made a member of the committee.

And now your committee comes and takes pleasure in reporting such facts as it has been able to gather for the information of the Board of Regents.

In the judgment of this committee, it was deemed necessary at the threshold of the investigations to ascertain with a greater degree of certainty the details of such plan as might be suggested and formulated by the associated colleges for the accomplishment of their wishes. For that purpose, therefore, a joint meeting of this committee with that of the colleges was recently held, in which the subject was discussed with commendable frankness and freedom. A record of the action of this joint meeting was preserved, and its official proceedings will probably best convey to your minds the extent and bearing of the questions involved in the proposition of the associated colleges. These proceedings are as follows:

A joint meeting of the Committees on Graduate Study of the Regents of the Smithsonian Institution and of the American Association of Agricultural Colleges and Experiment Stations was held December 27, 1899, in Washington, D. C., at the residence of Mr. J. B. Henderson, at his invitation. There were present of the Regents, Messrs. J. B. Henderson, A. Graham Bell, and R. R. Hitt; of the Association, M. H. Buckham, president of the University of Vermont; H. H. Goodell, president of the Massachusetts Agricultural College; Alexis Cope, secretary of Ohio State University; J. H. Washburn, president of the Agricultural and Mechanical College of Rhode Island; and A. C. True, Director of the Office of Experiment Stations. The meeting was called to order at 7.45 p. m. by Mr. Henderson, who suggested that a joint session be organized. On motion, Mr. Henderson was chosen chairman and Mr. True secretary. Mr. Buckham briefly explained the purpose of the Association in favoring the establishment of a Bureau of Graduate Study in the Smithsonian Institution, urged the importance of this step to the colleges and universities of the country, and explained that the Association comprised State universities as well as agricultural and mechanical colleges. The following outline plan for a Bureau of Graduate Study in the Smithsonian Institution was then read by the secretary, with the prefatory remark that it was merely tentative and had been drawn in definite terms to serve as a basis for discussion:

PLAN FOR BUREAU OF GRADUATE STUDY IN THE SMITHSONIAN INSTITUTION.

The Committee on Graduate Study of the American Association of Agricultural Colleges and Experiment Stations (including all the universities and colleges organized under the Morrill Act of 1862) asks the Smithsonian Institution to organize and conduct a Bureau of Graduate Study, having as its principal functions the following:

1. The keeping of a register of graduates of approved colleges and universities who desire opportunities for graduate study in connection with the different branches of the United States Government.
2. The conducting of negotiations with the different branches of the Government on behalf of registered graduates to secure for them opportunities for study and research according to their qualifications and aims.
3. The establishment and maintenance of lecture courses and seminars by specialists on the subjects on which researches are being made by the Government and the Smithsonian Institution.

The requirements of this Bureau shall be:

1. A competent chief to organize and manage it.
2. An office force to conduct the routine business.
3. A building for administration offices and lecture rooms.
4. An annual income to pay administrative officers, lecturers, and miscellaneous expenses.

Methods of securing the needed funds:

1. Ask Congress to provide without delay a new building for the National Museum, part of which may be utilized for the offices and lecture rooms of the Bureau of Graduate Study.
2. Ask Congress for an appropriation of $50,000 annually to pay running expenses, lectures, etc., including rental of temporary quarters until permanent building is provided.
3. Announce that the Smithsonian Institution will gladly receive funds from private sources for scientific researches in which graduates of American colleges may participate and the methods and results of which will be taught to graduate students connected with the Bureau.

Legislation required:

1. Act of Congress establishing the Bureau and defining its functions.
2. Appropriation for current expenses.
3. Appropriation for building for National Museum.
4. Act of Congress permitting officers of the Government participating in the work of Bureau to receive extra compensation for services performed outside of official hours; this compensation to be determined by regulations made by the Regents of the Smithsonian Institution.

Reasons why the Smithsonian Institution should undertake the management of a Bureau of Graduate Study:

1. The graduates of the universities and colleges of the United States need opportunities to utilize the libraries, collections, and special apparatus under control of the Government and to familiarize themselves with the technical and scientific operations of the Government. This principle has already been recognized by Congress in act of April 12, 1892, as regards institutions in the District of Columbia.
2. The National, State, and local governments and the people of the United States need the services of an increasing number of technical and scientific experts who can best be trained in special lines in connection with the Government work.
3. The Smithsonian Institution is regarded by the Government officers and by the universities and colleges of the country as a central agency for the promotion of higher scientific education and research. It is already a recognized leader in scientific enterprises in this country and only needs to broaden its operations somewhat to take up this new work. It has an invaluable basis for this work and its freedom from political influences gives it the confidence of the country. All its traditions regarding scientific work are right.
4. By allying itself with the universities and colleges and with the scientific Government bureaus, the Smithsonian Institution will strengthen its scientific leadership and be able more thoroughly to promote the increase and diffusion of knowledge. It will broaden its basis of support and have a better chance of securing public and private funds for research work of the highest order. It will thus be able to maintain and extend its leadership in science and grow in strength with the growth of universities throughout this country. As local scientific institutions develop in different parts of the country, is it not desirable that the Smithsonian Institution shall take an advance step in its relation with these institutions?

ATTITUDE OF THE AMERICAN ASSOCIATION OF AGRICULTURAL COLLEGES AND EXPERIMENT STATIONS.

If the Smithsonian Institution is declared to be favorable to the organization and maintenance of a Bureau of Graduate Study, this committee is authorized to pledge and does pledge the active support of the American Association of Agricultural Colleges and Experiment Stations toward the securing of the necessary legislation and funds for the establishment and support of the Bureau. If the Regents of the Smithsonian Institution so desire, this committee will take the initiative in seeking the introduction into Congress of bills for this purpose and in urging their passage, but only after an express assurance from the Regents that such action will receive their cordial indorsement and support.

TENTATIVE DRAFT OF ACT OF CONGRESS ESTABLISHING A BUREAU OF GRADUATE STUDY.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That there shall be and hereby is annually appropriated out of any money in the Treasury not otherwise appropriated, the sum of fifty thousand dollars for the year ending June thirtieth, nineteen hundred and one, and the same sum for each succeeding year, to enable the Regents of the Smithsonian Institution to organize and maintain a Bureau of Graduate Study for the purpose of securing for the graduates of the universities and colleges of the several States and Territories and of the District of Columbia, opportunities to utilize the libraries, scientific collections, apparatus, and laboratories owned by the United States and in charge of officers of the United States, for advanced studies and researches under regulations to be prescribed by the said Regents and as far as shall be mutually agreed upon between the said Regents and the heads of the several Executive Departments of the

Government, the Librarian of Congress, Commissioner of Labor, Commissioner of Fish and Fisheries, and the Secretary of the Smithsonian Institution, with due regard to the needs and requirements of the technical, scientific, and administrative work of the Government; and the said Regents are authorized to establish and maintain seminars and courses of lectures on subjects relating to the technical and scientific work of the Government and to employ experts and specialists for this purpose; and the heads of Departments and the other officers aforesaid are authorized to grant permission to officers and employees of the Government working under their direction to take part in the work of the Bureau of Graduate Study under direction of the said Regents, *Provided*, That such services shall not in any way interfere with the efficient discharge of their regular duties as Government officials, *And provided further*, That officers and employees of the Government may receive extra compensation on terms to be fixed by the said Regents for services actually performed for said Bureau of Graduate Study outside of the hours when their services are required for the discharge of their regular official duties.

And the said Regents are authorized to use the buildings and other property of the National Museum and to rent buildings as far as may be necessary for the work of said Bureau.

And the said Regents shall employ a person of scientific attainments and administrative experience as the chief of said Bureau and are authorized to employ assistants, experts, clerks, and other persons, as far as may be necessary to carry out the provisions of this act, and to incur expenses for traveling, printing, and all other purposes essential to the maintenance of said Bureau within the appropriations provided by the law.

Expenses.

Salary of chief	$4,000
Salary of assistant chief	2,000
Salary of two clerks (stenographers)	2,000
Salary of messenger and janitor	1,000
Salary of temporary employees	1,000
Compensation of 50 lecturers (average of 40 lectures in each course for $500), 2,000 lectures	25,000
Rent of temporary quarters, heat, lights, etc	5,000
Furniture, supplies, traveling expenses, etc	5,000
Printing and miscellaneous	5,000
Total	50,000

After the reading of this paper a free discussion of its contents was had, in which all present took part. At the conclusion of this discussion an understanding was reached that the committee of the Association would be satisfied with any effective plan by which graduates of the colleges and other qualified persons should be guided by the Smithsonian Institution in advanced studies and researches in connection with the facilities presented by the Government bureaus at Washington, and that this committee would await the action of the Regents of the Smithsonian Institution at their meeting in January, 1900.

Adjourned at 10 p. m.

A. C. True, *Secretary.*

Dr. William L. Wilson, who was unable to be present, sent the following letter to the chairman:

Washington and Lee University,
Lexington, Va., December 26, 1899.

My Dear General: The feeble hope I have been nursing, that I might be able to go to Washington to-morrow and meet with you and the gentlemen representing the land-grant colleges, has flickered out. I know the importance of this meeting and I am exceedingly desirous of hearing the college committee develop their plans and wishes.

The more I reflect on the question, in the light of my experience in Washington and as a college officer, the less able I find myself to formulate any plan on a scale such as doubtless these gentlemen desire. We are, I am sure, desirous that the Smithsonian Institution should meet their wishes as far as it can without swamping the larger work of research and of the diffusion of knowledge among men, which it was founded to do and which it has so well done.

But our resources are small, and even if adequately increased I do not see clearly how the work of research and of instruction can be made to go hand in hand. The best endowed universities have not been able to unite the two, except in a small and occasional way. The men who by scientific research have extended human knowledge are generally compelled to work in such individual and even eccentric ways that they can not carry learners with them, and they benefit the world by making known their results and methods, not by carrying with them a company of spectators, to whom every step must be explained and every process of reasoning made clear in advance.

Very sincerely, yours, Wm. L. Wilson.

At a subsequent meeting of the joint committees, held in this city, at the residence of Dr. Bell, on the 11th instant, in which President Harper, of the Chicago University, participated as a representative of the National Educational Association, other proceedings of an interesting character were had. Reports of these proceeding were promptly furnished by Dr. True to the Secretary of the Smithsonian Institution, and also by this committee.

At the possible risk of being tedious in the presentation of its report your committee deems it advisable to preserve a full record of the papers and documents connected with the propositions now submitted to the consideration of the Regents.

The report of Mr. True is as follows:

United States Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., January 12, 1900.

Mr. S. P. Langley,
Secretary, Smithsonian Institution, Washington, D. C.

Dear Sir: With a view to facilitating your consideration of the pending questions regarding the opening of the Smithsonian Institution and the Government departments to graduate students, permit me to lay before you a series of papers relating to this matter.

Exhibit A.—Report of the Committee on Graduate Study of the American Association of Agricultural Colleges and Experiment Stations, contained in Bulletin No. 65, Office of Experiment Stations, Department ot Agriculture.[1]

Exhibit B.—The Educational Review for December, 1899, containing an account of the action taken by a committee of the National Educational Association regarding the project for a National University at Washington.[1]

Exhibit C.—A tentative plan for a bureau of graduate study in the Smithsonian Institution, which was drawn up by the committee on graduate study of the Association of Agricultural Colleges and Experiment Stations and presented to the committee of the Regents of the Smithsonian Institution appointed to consider this matter.[2]

Exhibit D.—Copy of resolutions adopted by the George Washington Memorial Association at its annual meeting in December, 1899.

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[1] Being accessible in the publications mentioned, these exhibits are not printed here.

[2] This is identical with the document given above, p. xviii.

Exhibit E.—A summary of points on which there is agreement between the committees of the National Educational Association and the agricultural colleges, drawn up by President Harper and myself after a conference on this matter January 11, 1900.

I may add that all the plans which have been proposed by the three associations referred to in the above statement have been based on the idea that the Smithsonian Institution should be the leader in this enterprise, that it should have a free hand in the formation and execution of plans for carrying on this work, and that this new enterprise should be undertaken by the Smithsonian Institution only so far as it can obtain funds for the purpose from Congress and private sources. There is entire agreement on the proposition that the funds at present at the disposal of the Smithsonian Institution should not be used for this new work.

I am authorized by the committee on graduate study of the Association of Agricultural Colleges and Experiment Stations to act as their representative here, and as such I shall be glad to give you any further assistance in my power to make plain the attitude of this Association in this matter.

Very respectfully, yours,

A. C. True,
Secretary of Committee on Graduate Study of the Association of Agricultural Colleges and Experiment Stations.

Exhibit E.

Points of agreement between committee of National Educational Association and American Association of Agricultural Colleges and Experiment Stations, regarding the work which the Smithsonian Institution might undertake for the benefit of graduates of colleges and universities.

Memorandum made by President Harper, of Chicago University, of the committee of National Educational Association, and A. C. True, Director of the Office of Experiment Stations, of the committee of the American Association of Agricultural Colleges and Experiment Stations, January 11, 1900.

1. That the Regents of the Smithsonian Institution ask the Congress of the United States for a special appropriation for the work of research and investigation, to be conducted under their supervision by persons properly qualified therefor. Such work to be so conducted as to utilize the libraries, scientific collections, apparatus, and laboratories owned by the United States, and in charge of the officers of the United States, for investigations and researches, under regulations to be prescribed by the said Regents, and as far as shall be mutually agreed upon between the said Regents and the heads of the several Executive Departments of the Government, the Librarian of Congress, Commissioner of Labor, Commissioner of Fish and Fisheries, and the Secretary of the Smithsonian Institution, with a view of carrying out the policy of Congress, declared in the joint resolution of April 12, 1892.

2. That the Regents ask the general public for gifts of money, to be used in providing buildings, laboratories, equipments, and endowments, for purposes of instruction, such instruction to be limited to students who are graduates of properly accredited institutions or those who are otherwise properly qualified, it being understood that it shall not be the purpose of the Smithsonian Institution to confer degrees of any kind in connection with such instruction.

3. That the Regents formulate a plan for the appointment of an advisory board; the members of said board to represent the leading educational institutions of the country, with a view to securing the active cooperation of the colleges and universities of the country in carrying on this enterprise.

(No. 8.)

JOINT RESOLUTION to encourage the establishment and endowment of institutions of learning at the national capital by defining the policy of the Government with reference to the use of its literary and scientific collections by students.

Whereas large collections illustrative of the various arts and sciences and facilitating literary and scientific research have been accumulated by the action of Congress through a series of years at the national capital; and

Whereas it was the original purpose of the Government thereby to promote research and the diffusion of knowledge, and it is not the settled policy and present practice of those charged with the care of these collections specially to encourage students who devote their time to the investigation and study of any branch of knowledge by allowing to them all proper use thereof; and

Whereas it is represented that the enumeration of these facilities and the formal statement of this policy will encourage the establishment and endowment of institutions of learning at the seat of government, and promote the work of education by attracting students to avail themselves of the advantages aforesaid under the direction of competent instructors: Therefore,

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the facilities for research and illustration in the following and any other governmental collections now existing or hereafter to be established in the city of Washington for the promotion of knowledge shall be accessible, under such rules and restrictions as the officers in charge of each collection may prescribe, subject to such authority as is now or may hereafter be permitted by law, to the scientific investigators and to students of any institution of higher education now incorporated or hereafter to be incorporated under the laws of Congress or of the District of Columbia, to wit:

1. Of the Library of Congress.
2. Of the National Museum.
3. Of the Patent Office.
4. Of the Bureau of Education.
5. Of the Bureau of Ethnology.
6. Of the Army Medical Museum.
7. Of the Department of Agriculture.
8. Of the Fish Commission.
9. Of the Botanic Gardens.
10. Of the Coast and Geodetic Survey.
11. Of the Geological Survey.
12. Of the Naval Observatory.

Approved, April 12, 1892.

The papers already copied and referred to in this report are deemed amply sufficient to acquaint the Regents with the propositions made by the associated colleges.

And now, in conclusion, your committee does not hesitate to express its warm and decided sympathy with the general purposes of the movement thus made for your consideration. The object sought commends itself to us all, and the zeal and ability with which it has been pressed upon our consideration by the very able and distinguished educators and scientists connected with these colleges furnish ample assurance that the consummation of the great and leading object sought by them is only a question of time. The material already collected in the bureaus and departments of the Government furnishes a rich mine of educational wealth that will not be permitted to remain forever undeveloped. This material is now being constantly enriched by the most valuable additions to its present enormous wealth. Already it has invited to the national capital many distinguished scientists, anxious to avail themselves of the superior advantages thus offered for investigation and research.

Your committee, however, is painfully impressed with the fact that the powers of the Smithsonian Institution as at present organized are scarcely broad enough to embrace the work proposed. And the committee is equally impressed with the fact that even with enlarged authority its present financial condition would absolutely prevent anything like efficient and creditable performance of the work contemplated.

It is well known to the members of this Board that a great wealth of material—material which would be of immense utility in the successful accomplishment of the purposes indicated by the associated colleges, lies buried in the crypts and cellars of the National Museum.

If our Institution is unable for want of room, as it undoubtedly is, even to place this valuable material on exhibition for the public eye and as little able to arrange it for scientific uses, the problem of providing halls for lectures and meeting the necessary expenditures incident to the work proposed, becomes serious and formidable in the extreme.

Your committee is not prepared to make definite recommendations to the Board for its final or ultimate action.

That which is clearly inexpedient to-day may become not only expedient, but eminently desirable to-morrow.

If in your judgment the committee should retain its powers and report progress from time to time in the future, it will be our highest pleasure to comply with your further demands.

Yours, truly,
J. B. HENDERSON, *Chairman.*

SMITHSONIAN INSTITUTION,
Washington, D. C., January 23, 1900.

MY DEAR SENATOR HENDERSON:

At your request I hand back to you the letter which I sent you some time since in a personal capacity, now authorizing its use as in your discretion you may deem fit, though I do so with some hesitation, since it deals with a matter on which the Board has not yet defined its policy.

Under the circumstances, I can then, perhaps, be of most service by pointing out what the attitude of the Board has been under analogous circumstances in the past, and by indicating in a general way the present situation of the Institution and its relations to the scientific bureaus in Washington.

I will first comply with your request by citing the passage in the communication of the representatives of the American Association of Agricultural Colleges and Experiment Stations, concerning which you inquire. This passage reads as follows:

"The committee has thought that perhaps the Secretary and Regents might not look favorably upon the idea of constituting the Smithsonian the permanent agent for the control and direction of such graduate work, but that they might be willing to take the initiative in its organization and direction, and when the successful plan was fully developed, might generously relinquish its control to a separate and independent management."

Next, at your kind solicitation, I take this occasion to speak of the plan in question, which, you will remember, is but one of several plans. With these I have large sympathy, as with every step in aid of the higher education and research. Let me recall, however, not my opinions, but the decisions of Congress and the Regents.

After the Smithson bequest had been received by the Government, nearly ten years were employed by Congress in considering the form which the Institution should take. The most distinguished members in Congress and almost all the notable educators in this country expressed their opinions, and the proposal that the Institution should be more or less a teaching body, or in some way assimilable to a university, was most thoroughly discussed and embodied in various bills, which failed to become law. The proposal then was defeated, and its defeat created a policy for the Institution, which has been followed by the Regents up to this time.

I understand that the wish at present is to found a school of research by utilizing the existing scientific departments and the bureaus of the Government through the means of an administrative office *under the Smithsonian Institution.* This is, of course, to be managed by the Regents, and it is claimed that it can be supported by a small appropriation from Congress. I am not, then, considering the abstract merits or the difficulties of a proposal to found such a system of research, so much as the difficulties of establishing it under this Institution.

The proposition has much in its favor from one point of view; and yet it seems questionable whether this connection even furnishes the best means of producing the results anticipated when we consider that each scientific bureau and office has grown out of some practical need of the Government; that each at all times is occupied on practical work, and that each now looks to the head of its department and not to the Institution as having the sole right to direct any part of its affairs. Let me say, too, that in an important branch of science like physics, no bureau, with one unimportant exception, has any laboratory worth mentioning; that there is at present but one chemical laboratory in Washington which could be considered with reference to the admission of students, since in the rest not a score of students could be accommodated if a hundred applied; and that the Regents would almost necessarily be called upon to find means to create these costly accessories of the plan, although they are now representing to Congress the insufficiency of its appropriations to meet the needs of the special work which is already committed to them.

What is more important, the Smithsonian Institution has been founded and carried on with functions so distinct from that of teaching or of a university, that to create a new department in it for the proposed use would be like remaking the whole machinery of its action. The change that is proposed, though apparently superficial, is radical, and in advance of experiment no one knows where it will lead.

It is well, then, to consider here, that while the money question is of very great importance indeed, it is for the moment secondary. If some one desiring to conduct such a scheme were to offer to give outright to the Regents of the Institution a fund as large as its present one, which was to be used for managing a bureau of graduate study and research (and I should consider even this amount insufficient), I should, if my opinion were sought, ask to have the plan considered only with the understanding that this Institution was distinctly altering its functions in accepting the money for such a purpose.

These gentlemen suggest an appropriation of something like $50,000, which I understand them to believe will be sufficient, because of their hope to secure continuous voluntary work by the gratuitous or nearly unpaid contributions of our local men of science. This sum would, however, I think, prove wholly inadequate. Being myself long a student of science here, I may be allowed to say that while in my own knowledge there are some who like to teach and would do it without reward, and do it well, they are in an almost negligible proportion to the large number who have (it should always be remembered) accepted the lower salaries given here, as against higher ones they could obtain in colleges and universities, because no condition of tuition is now attached to their work of research.

If upon careful consideration it is found that the scientific departments and bureaus of the Government could be advantageously used in connection with other agencies as auxiliaries for post-graduate study, without interfering with their primary functions, I, for one, should be glad to see this done. The Institution and all its branches are now and always have been open to any properly accredited investigator so far as the limited accommodations and the regular work permit.

The communication under consideration by your committee comes from representatives of the agricultural colleges and agricultural experiment stations created, in the main, by the General Government. Their relations to it have always been intimate, and they present the most important outcome of Congressional action for the higher education, each State in the Union having such a college and experiment station. The gentlemen who represent these organizations do not stand in the position of ordinary educators, but are accustomed to deal with Government affairs, whether with State legislatures or members of Congress, and it is in the course of natural development that they should seek to crown their system by a great school of research in Washington, connected more or less directly with the General Government. I think their aspiration is a most legitimate one, and I believe that they represent a body of men who in some way or other are very likely to succeed in any well-matured plans which they deliberately set out to accomplish.

Since the permissive act of 1892, however, no bureau, within my knowledge, has taken official advantage of the powers already granted, and I think that this indicates the feeling which these bureaus may be expected to entertain toward an agent invested by Congress with larger authority. The responsibility as well as the danger and trouble of organizing this scarcely formulated plan, and accepting the often ungracious task of engrafting it on bureaus of the Government not otherwise under the control of the Institution—in short, of bearing the brunt of the struggle for it in its early years—would fall on the Smithsonian Institution, whose present kindly relations with these bureaus I should be sorry to see jeopardized.

Let me say (if in conclusion I may venture to express a personal opinion) that it is at least certain that the Institution can not draw back from a line of action to which it is once morally committed, and that ordinary prudence indicates the need of care in acquiring at its own risk a knowledge of the effect which this radical change might make in its future.

Very respectfully, yours,

S. P. Langley.

Hon. J. B. Henderson,
Chairman of Special Committee of the Board of Regents, Washington, D. C.

Castle Creek, Hot Springs,
Yavapai County, Ariz., January 20, 1900.

Dear Mr. Langley: I regret that I shall not be able to attend the annual meeting of the Regents.

I suppose the most important subject that will come before the Regents will be the application of the agricultural colleges for some form of connection with the Institution, through which select graduates of those colleges may secure advanced instruction in science and in scientific research, in the bureaus under its administration. I feel much interested in this question, and regret that I am under the disability of not knowing the definite proposition of the colleges and of not having conferred with my associates on the committee appointed at the last meeting of the Regents. Without these lights, it seems to me that many difficulties and much misapprehension must be cleared away, before any safe and practicable plan can be reached, looking toward the end proposed. That end proposes a diversion of the Institution and of its scientific bureaus from the main work they were founded to accomplish, and such diversion if suddenly and sharply made, will lessen their present efficiency without accomplishing the new results. To receive any considerable number of students and give them proper guidance and fair opportunites of work, would certainly interfere, seriously, with the regular operation of the Institution and of its affiliated bureaus.

It is impracticable to turn aside men engaged in research to the work of instruction, as a rule, and only a limited number of such men have any aptitude or taste for such work. Specialists accept positions under the Government at less salaries than colleges would pay them because they do not have to teach, and because they can pursue their researches in their own individual ways, and wherever the local advantages are most favorable. By this method their work inures to the benefit of all the educational institutions of the country, and the scientific and economic world gets the fruits of that work. It is also true, that collections are destroyed in the regular work of instruction, and that most of the collections in the National Museum and scientific bureaus are consequently available only for the individual and advanced investigator, toward whom the most liberal policy should be, as I feel sure, it always has been, adopted.

These are some of the views which have occurred to me, and some of the many difficulties to be reckoned with, in any movement in the direction proposed. I need not say that I am fully in accord with what I feel sure, is the general wish of the Regents—to meet the request of the colleges, in the most sympathetic and friendly spirit, and to extend to them the fullest and freest access to every source and facility of information, under the control or influence of the Institution, or that can be made compatible with its administration. Yet it seems to me that any beginning of a new and wider policy, must keep carefully in view the continued success and preeminence of the Institution itself in its chosen field, and the further fact that the scientific bureaus of the Government have been established and are maintained more for practical and economic purposes than for strictly scientific purposes, and only incidentally or occasionally for the work of instruction, save as involved in their regular work.

Very truly, yours, Wm. L. Wilson.

Mr. S. P. Langley,
Secretary of the Smithsonian Institution.

A very general discussion arose, participated in by Senators Cullom and Platt, and Messrs. Henderson, Hitt, Bell, and others.

Senator Cullom stated that this might end in the Institution's resources being scattered and in its becoming simply a place of learning, school, or college, or university. He did not think that was the purpose of the founder, but that the more separately it maintained itself, the freer would be the position of the Institution in the end, and that to put the matter on record he would move

That the report be accepted and printed and that the committee be discharged.

Mr. Platt then moved

That the report be accepted, but that the committee be continued.

Mr. Bell observed that the matter was too important to be passed over briefly, that a very great many of its details might perhaps be impracticable, but that some features were practicable, and that it came, he thought, within the functions of the Institution to carry them out, possibly by the help of Congress.

After some further remarks, Mr. Bell offered the following resolution:

In order to facilitate the utilization of the Government Departments for the purposes of research—in pursuance of the policy enunciated by Congress in a joint resolution approved April 12, 1892—

Resolved, That Congress be asked to provide for an Assistant Secretary of the Smithsonian Institution in charge of research in the Government Departments, whose duty it shall be to ascertain and make known what facilities for research exist in the Government Departments, and arrange with the heads of Departments, and with the officers in charge of Government collections, rules and regulations under which suitably qualified persons may have access to the Government collections for the purposes of research, with due regard to the needs and requirements of the work of the Government; and it shall also be his duty to direct the researches of such persons into lines which will promote the interests of the Government, and the development of the natural resources, agriculture, manufactures, and commerce of the country, and (generally) promote the progress of science and the useful arts and the increase and diffusion of knowledge among men.

The Chancellor ruled that the resolution was not in order until the report had been disposed of, and the discussion was continued on Senator Cullom's motion, turning on the advisability of continuing the committee, Senator Henderson, the chairman, remarking that if the committee were continued it should be instructed as to the wishes of the Board.

Mr. Adams said that he thought it would be better to take some decisive action; that if it were not thought within the province of the Institution to undertake this it would be franker to say so, in order that the people who were looking to the Institution for help could turn elsewhere, and that he thought it would be better for the movement itself that some such positive statement should be made now and not postpone the matter, giving these gentlemen ground for hope that the Institution would do something favorable.

The Chancellor observed that it was open to these gentlemen themselves to go to Congress and obtain the assistance they desired.

There were further remarks by different Regents on Senator Cullom's motion, when upon the suggestion that it would be considerate to the committee to use instead of the word "discharged" some other expression which would give a similar meaning, Mr. Hitt said that a motion to accept, like a motion to adopt, carried with it the discharge of the committee.

Senator Cullom by consent modified his motion by omitting any reference to the "discharge" of the committee.

Senator Platt said he would not insist on the motion that the committee be continued.

The Chancellor then put the motion as modified, "That the report be accepted and printed," and it was adopted without any dissenting voice.

Mr. Bell then moved the adoption of his resolution, but it being now a quarter to 12 o'clock, the Chancellor and the Congressional Regents were obliged to leave, and it was voted to adjourn to meet again on the call of the Chancellor and the Secretary, leaving Mr. Bell's resolution pending for consideration at some future meeting.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION

FOR THE YEAR ENDING JUNE 30, 1900.

To the Board of Regents of the Smithsonian Institution:

Your Executive Committee respectfully submits the following report in relation to the funds of the Institution, the appropriations by Congress, and the receipts and expenditures for the Smithsonian Institution, the U. S. National Museum, the International Exchanges, the Bureau of Ethnology, the National Zoological Park, and the Astrophysical Observatory for the year ending June 30, 1900, and balances of former years:

SMITHSONIAN INSTITUTION.

Condition of the Fund July 1, 1900.

The amount of the bequest of James Smithson deposited in the Treasury of the United States, according to act of Congress of August 10, 1846, was $515,169. To this was added by authority of Congress, February 8, 1867, the residuary legacy of Smithson, savings from income and other sources, to the amount of $134,831.

To this also have been added a bequest from James Hamilton, of Pennsylvania, of $1,000; a bequest of Dr. Simeon Habel, of New York, of $500; the proceeds of the sale of Virginia bonds, $51,500; a gift from Thomas G. Hodgkins, of New York, of $200,000 and $8,000, being a portion of the residuary legacy of Thomas G. Hodgkins, and $1,000, the accumulated interest on the Hamilton bequest, making in all, as the permanent fund, $912,000.

The Institution also holds the additional sum of $42,000, received upon the death of Thomas G. Hodgkins, in registered West Shore Railroad 4 per cent bonds, which were, by order of this committee, under date of May 18, 1894, placed in the hands of the Secretary of the Institution, to be held by him subject to the conditions of said order.

Statement of the receipts and expenditures from July 1, 1899, to June 30, 1900.

RECEIPTS.

Cash on hand July 1, 1899		$74,703.42	
Interest on fund July 1, 1899	$27,360.00		
Interest on fund January 1, 1900	27,360.00		
		54.720.00	
Interest to January 1, 1900, on West Shore bonds		1,680.00	
			$131,103.42
Cash from sales of publications		277.84	
Cash from repayments, freight, etc		4,131.97	
			4,409.81
Total receipts			135,513.23

EXPENDITURES.

Building:			
Repairs, care, and improvements	$7,376.30		
Furniture and fixtures	524.22		
		$7,900.52	
General expenses:			
Postage and telegraph	364.88		
Stationery	830.47		
Incidentals (fuel, gas, etc.)	4,644.36		
Library (books, periodicals, etc.)	2,950.97		
Salaries[1]	20,576.39		
Gallery of art	356.01		
Meetings	136.96		
		29,860.04	
Publications and researches:			
Smithsonian contributions	1,450.17		
Miscellaneous collections	1,469.14		
Reports	2,042.34		
Researches	6,326.91		
Apparatus	224.81		
Hodgkins fund	4,029.95		
Explorations	1,400.00		
		16,943.32	
Literary and scientific exchanges		4,590.28	
			59,294.16
Balance unexpended June 30, 1900			76,219.07

The cash received from the sale of publications, from repayments for freights, etc., is to be credited to the items of expenditure, as follows:

Smithsonian contributions	$26.37	
Miscellaneous collections	191.08	
Reports	24.79	
Special publicatious	35.60	
		$277.84

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[1] In addition to the above $20,576.39 paid for salaries under general expenses, $8,176.47 were paid for services, viz, $2,875.58 charged to building account, $999.95 to Hodgkins fund account, $1,648.02 to library account, $2,289.92 to researches account, and $363 to furniture account.

Exchanges	$2,598.20	
Incidentals	508.77	
Explorations	1,000.00	
Salaries	25.00	
		$4,409.81

The net expenditures of the Institution for the year ending June 30, 1900, were therefore $54,884.35, or $4,409.81 less than the gross expenditures, $59,294.16, as above stated.

All moneys received by the Smithsonian Institution from interest, sales, refunding of moneys temporarily advanced, or otherwise, are deposited with the Treasurer of the United States to the credit of the Secretary of the Institution, and all payments are made by his checks on the Treasurer of the United States.

Your committee also presents the following statements in regard to appropriations and expenditures for objects intrusted by Congress to the care of the Smithsonian Institution:

Detailed statement of disbursements from appropriations committed by Congress to the care of the Smithsonian Institution for the fiscal year ending June 30, 1900, and from balances of former years.

INTERNATIONAL EXCHANGES, SMITHSONIAN INSTITUTION, 1900.

RECEIPTS.

Appropriated by Congress for the fiscal year ending June 30, 1900, "for expenses of the system of international exchanges between the United States and foreign countries, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees and the purchase of necessary books and periodicals" (sundry civil act, March 3, 1899)	$24,000.00

DISBURSEMENTS.

[From July 1, 1899, to June 30, 1900.]

Salaries or compensation:	
1 curator, 12 months, at $225	$2,700.00
1 chief clerk, 12 months, at $175	2,100.00
1 clerk, 12 months, at $150	1,800.00
1 clerk, 12 months, at $116.67	1,400.03
1 clerk, 12 months, at $100	1,200.00
1 clerk, 2 months, at $100	200.00
1 clerk, 12 months, at $80	960.00
1 clerk, 5 months, at $75; 7 months, at $90	1,005.00
1 packer, 11½ months, at $55	632.50
1 workman, 12 months, at $50	600.00
1 copyist, 12 months, at $45	540.00
1 copyist, 8 months 47 days, at $45	428.93
1 messenger, 7 months 11 days, at $25	184.16
1 messenger, 3½ months 8 days, at $25	93.95
1 laborer, 273 days, at $1.50; 1½ months, at $45	477.00
1 cleaner, 156 days, at $1	156.00
1 agent, 12 months, at $50	600.00
1 agent, 12 months, at $91.66⅔	1,100.00
1 agent, 12 months, at $14.33⅓	172.00
Total salaries or compensation	16,349.57

General expenses:			
Books	$5.00		
Freight	3,548.68		
Packing boxes	993.80		
Postage and telegraph	202.00		
Stationery and supplies	324.32		
Traveling expenses	37.80		
		$5,111.60	
Total disbursements			$21,461.17
Balance July 1, 1900			2,538.83

INTERNATIONAL EXCHANGES, 1899.

Balance July 1, 1899, as per last report			$1,829.33

DISBURSEMENTS.

Salaries or compensation:			
1 agent, 6 months, at $50	$300.00		
1 agent, 6 months, at $91.66⅔	550.00		
1 agent, 6 months, at $13.66⅔	82.00		
		$932.00	
General expenses:			
Books	20.00		
Freight	779.16		
Stationery and supplies	71.68		
Traveling expenses	24.90		
		895.74	
Total disbursements			$1,827.74
Balance July 1, 1900			1.59

INTERNATIONAL EXCHANGES, 1898.

Balance July 1, 1899, as per last report	$6.11

DISBURSEMENTS.

General expenses:	
Books	5.00
Balance	1.11

Balance carried, under the provisions of the Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1900.

AMERICAN ETHNOLOGY, 1900.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1900, "for continuing ethnological researches among the American Indians, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees and the purchase of necessary books and periodicals, fifty thousand dollars, of which sum not exceeding one thousand dollars may be used for rent of building." (Sundry civil act, March 3, 1899)	$50,000.00

The actual conduct of these investigations has been continued by the Secretary in the hands of Maj. J. W. Powell, director of the Bureau of American Ethnology.

DISBURSEMENTS.

Salaries or compensation:			
1 director, 12 months, at $375		$4,500.00	
1 ethnologist in charge, 12 months, at $333.33		3,999.96	
1 ethnologist, 12 months, at $208.33		2,499.96	
1 ethnologist, 12 months, at $200		2,400.00	
1 ethnologist, 12 months, at $166.67		2,000.04	
1 ethnologist, 12 months, at $166.67		2,000.04	
1 ethnologist, 9 months 10 days, at $166.67		1,555.59	
1 ethnologist, 12 months, at $125		1,500.00	
1 ethnologist, 12 months, at $125		1,500.00	
1 ethnologist, 12 months, at $125		1,500.00	
1 ethnologic translator, 7 months, at $125		875.00	
1 illustrator, 12 months, at $166.67		2,000.04	
1 proof reader, 5 months, at $75		375.00	
1 library assistant, 5½ months, at $60		330.00	
1 library assistant, 1 month 25 days, at $50		90.32	
1 clerk, 12 months, at $100		1,200.00	
1 clerk, 12 months, at $100		1,200.00	
1 clerk, 10 months, at $100		1,000.00	
1 clerk, 3 months, at $100		300.00	
1 clerk, 2 months, at $100		200.00	
1 clerk, 12 months, at $75		900.00	
1 clerk, 3½ months 4½ days, at $60		218.70	
1 messenger, 12 months, at $50		600.00	
1 skilled laborer, 12 months, at $60		720.00	
1 laborer, 12 months, at $60		720.00	
1 laborer, 12 months, at $45		540.00	
1 laborer, 3 days, at $1.50		4.50	
1 laborer, 8½ days, at $1		8.50	
Total salaries or compensation		34,737.65	
General expenses:			
Books	$1,600.42		
Drawings	498.30		
Freight	241.55		
Lighting	54.34		
Furniture	419.05		
Manuscript	1,391.44		
Miscellaneous	69.90		
Postage and telegraph	57.50		
Publications	20.00		
Rental	916.63		
Special services	162.20		
Specimens	3,820.00		
Stationery, supplies, etc	1,218.76		
Traveling expenses	2,644.91		
		13,115.00	
Total disbursements			$47,852.65
Balance July 1, 1900			2,147.35

AMERICAN ETHNOLOGY, 1899.

Balance July 1, 1899, as per last report	$3,035.00

DISBURSEMENTS.

General expenses:		
Books	$224.12	
Drawings and illustrations	169.00	
Freight	86.68	
Lighting	22.55	
Manuscript	43.50	
Miscellaneous	9.00	
Postage and telegraph	52.95	
Rental	83.33	
Specimens	1,815.25	
Supplies	94.14	
Traveling expenses	342.00	
Total		$2,942.52
Balance July 1, 1900		92.48

AMERICAN ETHNOLOGY, 1898.

Balance July 1, 1899, as per last report		$35.36

DISBURSEMENTS.

General expenses	$20.50	
Postage and telegraph	8.47	
Total		28.97
Balance		6.39

Balance carried, under the provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1900.

NATIONAL MUSEUM—PRESERVATION OF COLLECTIONS, 1900.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1900, "for continuing the preservation, exhibition, and increase of the collections from the surveying and exploring expeditions of the Government and from other sources, including salaries or compensation of all necessary employees, $170,000, of which sum $5,000 may be used for necessary drawings and illustrations for publications of the National Museum" (sundry civil act, March 3, 1899)	$170,000.00

EXPENDITURES.

Services	$145,476.10		
Special services	1,226.30		
Total services		$146,702.40	
Miscellaneous:			
Drawings and illustrations	483.50		
Supplies	3,270.33		
Stationery	1,403.75		
Specimens	4,806.34		
Travel	2,063.53		
Freight	2,136.33		
Total miscellaneous		14,163.78	
Total expenditures			160,866.18
Balance July 1, 1900			9,133.82

Analysis of expenditures for salaries or compensation.

Scientific staff:		
1 executive curator, 12 months, at $291.66	$3,499.92	
1 head curator, 12 months, at $291.66	3,499.92	
1 head curator, 12 months, at $291.66	3,499.92	
1 curator, 12 months, at $200	2,400.00	
1 curator, 12 months, at $200	2,400.00	
1 curator, 12 months, at $200	2,400.00	
1 curator, 11 months, at $208.33	2,291.63	
1 curator, 12 months, at $175	2,100.00	
1 acting curator, 12 months, at $150	1,800.00	
1 assistant curator, 12 months, at $150	1,800.00	
1 assistant curator, 12 months, at $130	1,560.00	
1 assistant curator, 12 months, at $150	1,800.00	
1 assistant curator, 12 months, at $125	1,500.00	
1 assistant curator, 12 months, at $125	1,500.00	
1 assistant curator, 12 months, at $116.66	1,399.92	
1 assistant curator, 12 months, at $150	1,800.00	
1 assistant curator, 12 months, at $100	1,200.00	
1 assistant curator, 12 months, at $150	1,800.00	
1 assistant curator, 12 months, at $133.33	1,599.96	
1 second assistant curator, 12 months, at $100	1,200.00	
1 aid, 12 months, at $70	840.00	
1 aid, 12 months, at $60	720.00	
1 aid, 12 months, at $75	900.00	
1 aid, 12 months, at $50	600.00	
1 aid, 11 months 22 days, at $75	878.23	
1 aid, 12 months, at $100	1,200.00	
1 aid, 12 months, at $100	1,200.00	
1 aid, 12 months, at $75	900.00	
1 aid, 12 months, at $50	600.00	
1 aid, 12 months. at $100	1,200.00	
		$50,089.50
Preparators:		
1 photographer, 12 months, at $158.33	1,899.96	
1 modeler, 11 months 30 days, at $100	1,200.00	
1 osteologist, 12 months, at $90	1,080.00	
1 preparator, 12 months, at $80	960.00	
1 preparator, 12 months, at $70	840.00	
1 preparator, 12 months, at $80	960.00	
1 preparator, 12 months, at $45	540.00	
1 preparator, 1 month 7 days, at $75	91.94	
1 preparator, 12 months, at $80	960.00	
1 preparator, 12 months, at $45	540.00	
1 preparator, 12 months, at $60	720.00	
1 preparator, 3 months 70 days, at $75	398.79	
1 taxidermist, 12 months, at $60	720.00	
1 taxidermist, 12 months, at $90	1,080.00	
1 taxidermist, 12 months. at $100	1,200.00	
		13,190.69
Clerical staff:		
1 chief clerk, 12 months, at $208.33⅓	2,500.00	
1 editor, 12 months, at $167	2,004.00	
1 chief of division, 12 months, at $200	2,400.00	

Clerical staff—Continued.

1 registrar, 12 months, at $167	$2,004.00	
1 disbursing clerk, 12 months, at $116.67	1,400.04	
1 assistant librarian, 12 months, at $117	1,404.00	
1 stenographer and typewriter, 2 months 22 days, at $50	136.67	
1 stenographer, 9 months 12 days, at $75	705.00	
1 stenographer, 10 months 1 day, at $50	501.61	
1 stenographer and typewriter, 28 days, at $50	46.72	
1 stenographer and typewriter, 1 month 30 days, at $50	99.78	
1 stenographer and typewriter, 3 months 13 days, at $50	170.97	
1 stenographer and typewriter, 10 months 19 days, at $50	530.65	
1 stenographer and typewriter, 2 months, at $50; 2 months and 29 days, at $75	322.50	
1 stenographer and typewriter, 12 months, at $115	1,380.00	
1 stenographer, 12 months, at $150	1,800.00	
1 typewriter, 12 months, at $65	780.00	
1 typewriter, 12 months, at $50	600.00	
1 clerk, 12 months, at $83.34	1,000.08	
1 clerk, 12 months, at $100	1,200.00	
1 clerk, 12 months, at $90	1,080.00	
1 clerk, 12 months, at $50	600.00	
1 clerk, 12 months, at $55	660.00	
1 clerk 12 months, at $55	660.00	
1 clerk, 12 months, at $60	720.00	
1 clerk, 12 months, at $115	1,380.00	
1 clerk, 12 months, at $75	900.00	
1 finance clerk, 12 months, at $110	1,320.00	
1 acting property clerk, 12 months, at $50	600.00	
1 clerk, 11 months 29 days, at $45	538.50	
1 clerk, 11 months 28 days, at $55	656.33	
1 clerk, 12 months, at $50	600.00	
1 clerk and preparator, 12 months, at $50	600.00	
1 clerk, 12 months, at $90	1,080.00	
1 clerk, 12 months, at $50	600.00	
1 clerk, 12 months, at $50	600.00	
1 clerk, 12 months, at $70	840.00	
1 clerk, 12 months, at $115	1,380.00	
1 clerk and preparator, 12 months, at $75	900.00	
1 clerk, 6 months, at $100	600.00	
1 document clerk, 12 months, at $50	600.00	
1 clerk, 12 months, at $90	1,080.00	
1 copyist, 12 months, at $35	420.00	
1 copyist, 12 months, at $55	660.00	
1 copyist, 276 days, at $50 per month	462.57	
1 copyist, 2 months 58 days, at $50	195.76	
1 copyist, 12 months, at $40	480.00	
1 copyist, 7 months 10 days, at $35	257.50	
1 copyist, 12 months, at $50	600.00	
1 copyist, 12 months, at $35	420.00	
1 copyist, 12 months. at $50	600.00	
1 copyist, 12 months, at $30	360.00	
1 copyist, 8 months 99½ days, at $40	450.71	
		$43,887.39

Buildings and labor:

1 general foreman, 12 months, at $115	$1,380.00
1 foreman, 12 months, at $50	600.00
1 chief of watch, 12 months, at $65	780.00
1 chief of watch, 11 months 28 days, at $65	773.71
1 chief of watch, 12 months, at $65	780.00
1 watchman, 7 months 40 days, at $50	414.52
1 watchman, 29 days, at $45	42.77
1 watchman, 11 months 30 days, at $45	538.55
1 watchman, 8 months 16 days, at $45	383.23
1 watchman, 10 months 59 days, at $50	596.72
1 watchman, 12 months, at $50	600.00
1 watchman, 12 months, at $50	600.00
1 watchman, 8 months 27 days, at $65	576.61
1 watchman, 12 months, at $45	540.00
1 watchman, 12 months, at $45	540.00
1 watchman, 12 months, at $60	720.00
1 watchman, 12 months, at $60	720.00
1 watchman, 12 months, at $50	600.00
1 watchman, 12 months, at $50	600.00
1 watchman, 12 months, at $50	600.00
1 watchman, 12 months, at $45	540.00
1 watchman, 12 months, at $45	540.00
1 watchman, 6 months 14 days, at $50	322.58
1 watchman, 12 months, at $50	600.00
1 watchman, 12 months, at $45	540.00
1 watchman, 12 months, at $30	360.00
1 watchman, 3 months 15 days, at $45	156.77
1 watchman, 12 months, at $45	540.00
1 watchman, 12 months, at $50	600.00
1 watchman, 12 months, at $50	600.00
1 watchman, 10 months 43 days, at $45	513.68
1 workman, 325½ days, at $1.50	488.25
1 plasterer, 8 days, at $2	16.00
1 workman, 259 days, at $1.50	388.50
1 workman, 313 days, at $1.50	469.50
1 skilled laborer, 4 months, at $83.33	333.32
1 skilled laborer, 5 months 15 days, at $40	219.35
1 skilled laborer, 12 months, at $50	600.00
1 skilled laborer, 7 months 97 days, at $60	610.44
1 skilled laborer, 12 months, at $50	600.00
1 laborer, 182 days, at $1.50	273.00
1 laborer, 313 days, at $1.50	469.50
1 laborer, 69 days, at $1.50	103.50
1 laborer, 136 days, at $1.50	204.00
1 laborer, 2 months, at $34.50; 2 months, at $31.50; 2 months, at $33; 5 months, at $30; 1 month, at $37.50	385.50
1 laborer, 12 months, at $40	480.00
1 laborer, 5 months 15 days, at $45	246.77
1 laborer, 313 days, at $1.50	469.50
1 laborer, 313 days, at $1.50	469.50
1 laborer, 152 days, at $1.50	228.00
1 laborer, 327 days, at $1.50	490.50

Buildings and labor—Continued.		
1 laborer, 159 days, at $1.50	$238.50	
1 laborer, 337 days, at $1.50	505.50	
1 laborer, 275 days, at $1.50	412.50	
1 laborer, 313 days, at $1.50	469.50	
1 laborer, 349 days, at $1.50	523.50	
1 laborer, 313 days, at $1.50	469.50	
1 laborer, 313 days, at $1	313.00	
1 laborer, 328½ days, at $1.50	492.75	
1 laborer, 237½ days, at $1.50	356.25	
1 laborer, 313 days, at $1	313.00	
1 laborer, 25 days, at $1.50	37.50	
1 laborer, 313 days, at $1.50	469.50	
1 laborer, 313 days, at $1	313.00	
1 laborer, 19 days, at $1.50	28.50	
1 laborer, 12 months, at $40	480.00	
1 laborer, 321½ days, at $1.50	482.25	
1 laborer, 313 days, at $1.50	469.50	
1 laborer, 294 days, at $1.50	441.00	
1 laborer, 313 days, at $1.50	469.50	
1 laborer, 343 days, at $1.50	514.50	
1 laborer, 255 days, at $1.50	382.50	
1 laborer, 14 days, at $1.50	21.00	
1 laborer, 313½ days, at $1.50	470.25	
1 messenger, 12 months, at $40	480.00	
1 messenger, 12 months, at $25	300.00	
1 messenger, 9 months 15 days, at $25	237.50	
1 messenger, 12 months, at $25	300.00	
1 messenger, 12 months, at $25	300.00	
1 messenger, 6 months 16 days, at $50	325.81	
1 attendant, 1½ days, at $1	1.50	
1 attendant, 12 months, at $40	480.00	
1 cleaner, 10 months 7 days, at $30	306.77	
1 cleaner, 12 months, at $30	360.00	
1 cleaner, 12 months, at $30	360.00	
1 cleaner, 9½ days, at $1	9.50	
1 cleaner, 5 months, at $30	150.00	
1 cleaner, 11 months 5 days, at $30	335.00	
1 cleaner, 12 months, at $30	360.00	
1 cleaner, 1 month 11 days, at $30	40.65	
1 cleaner, 1 month 15 days, at $30	44.52	
		$38,308.52
Total services		145,476.10

NATIONAL MUSEUM—PRESERVATION OF COLLECTIONS, 1899.

Balance as per report July 1, 1899	$4,661.94

EXPENDITURES.

Services	$25.00	
Special services	313.15	
Total services		$338.15
Miscellaneous:		
Supplies	$899.27	
Stationery	425.83	

Miscellaneous—Continued.			
Specimens	$1,365.25		
Travel	931.21		
Freight	700.70		
Total miscellaneous		$4,322.26	
Total expenditures			$4,660.41
Balance July 1, 1900			1.53

PRESERVATION OF COLLECTIONS, 1899.

Total statement of receipts and expenditures.

RECEIPTS.

Appropriation by Congress July 1, 1898	$165,000.00

EXPENDITURES.

Salaries or compensation	$148,393.54		
Special services	2,654.65		
Total services		$151,048.19	
Miscellaneous:			
Supplies	3,665.28		
Stationery	1,196.00		
Specimens	5,146.69		
Travel	2,024.31		
Freight	1,918.00		
Total miscellaneous		13,950.28	
Total expenditures			164,998.47
Balance July 1, 1900			1.53

NATIONAL MUSEUM—PRESERVATION OF COLLECTIONS, 1898.

Balance as per report July 1, 1899	$97.28

EXPENDITURES.

Special services	$80.00	
Books	8.00	
Total expenditures		88.00
Balance		9.28

Balance carried, under the provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1900.

NATIONAL MUSEUM—FURNITURE AND FIXTURES, 1900.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1900, "for cases, furniture, fixtures, and appliances required for the exhibition and safe-keeping of the collections of the National Museum, including $10,000 for furnishing galleries, and including salaries or compensation of all necessary employees	$25,000.00

EXPENDITURES.

	Regular.	Galleries.	Total.
Salaries or compensation	$7,853.77	$3,918.50	$11,772.27
Special service	27.22		27.22
Total services	7,880.99	3,918.50	11,799.49
Miscellaneous:			
Exhibition cases	867.00	1,587.00	2,987.50
Storage cases	533.50		
Drawers, trays, etc	394.90	2,068.50	2,463.40
Frames and woodwork	282.72	145.02	427.74
Glass	1,166.57	749.40	1,915.97
Hardware	604.95	629.33	1,234.28
Tools	137.19	4.60	141.79
Cloth	58.31	14.00	72.31
Glass jars	222.81		222.81
Lumber	1,175.43	574.36	1,749.79
Paints, oils, etc	516.85	4.00	520.85
Office furniture	432.50		432.50
Leather and rubber	88.45	8.16	96.61
Iron brackets	71.37		71.37
Drawings for cases	143.75		143.75
Slate, cement, etc	35.50		35.50
Travel	2.00		2.00
Linoleum	107.10		107.10
Total miscellaneous	6,840.90		
Total regular account	14,721.89		
Total galleries account		6,702.87	
Total expenditure			24,424.76
Balance July 1, 1900			575.24

NATIONAL MUSEUM—FURNITURE AND FIXTURES, 1900.

Salaries or compensation:

1 supervisor of construction, 12 months, at $115	$1,380.00
1 carpenter, 62 days, at $3	186.00
1 carpenter, 257½ days, at $3	784.50
1 carpenter, 261 days, at $3	483.00
1 carpenter, 80 days, at $3	240.00
1 carpenter, 131 days, at $3	393.00
1 carpenter, 156 days, at $3	468.00
1 carpenter, 314 days, at $3	942.00
1 carpenter, 313 days, at $3	939.00
1 carpenter, 314 days, at $3	942.00
1 carpenter, 239½ days, at $3	718.50
1 carpenter, 313 days, at $3	939.00
1 carpenter, 17 days, at $3	51.00
1 cabinetmaker, 309 days, at $2.25	695.25
1 painter, 11 months, at $65; 1 month, at $67	782.00
1 skilled laborer, 9 months, at $60	540.00
1 skilled laborer, 9 months 39 days, at $60; 1 month, at $64	680.77
1 skilled laborer, 104 days, at $2	208.00
1 skilled laborer, 79 days, at $2	158.00
1 skilled laborer, 53 days, at $2	106.00
1 laborer, 13 days, at $1.50	19.50
1 laborer, 79 days, at $1.25	98.75
1 laborer, 12 days, at $1.50	18.00
	11,772.27

NATIONAL MUSEUM—FURNITURE AND FIXTURES, 1899.

Balance as per report July 1, 1899 .... $995.28

EXPENDITURES.

	Regular.	Galleries.	Total.
Salaries or compensation	$23.00		
Special services	2.00		
Total services	25.00		$25.00
Miscellaneous:			
Drawers, trays, etc	29.55		29.55
Frames and woodwork	17.35	$146.69	164.04
Hardware	153.18	106.40	259.58
Tools	3.10		3.10
Cloth	30.58		30.58
Glass jars	37.46		37.46
Lumber	62.37	304.24	366.61
Paints, oils, etc	8.63		8.63
Office furniture	14.50		14.50
Leather and rubber	1.68		1.68
Drawings for cases		47.00	47.00
Plumbing	16.20		16.20
Total miscellaneous	374.60	604.33	1,003.93
Total regular account	399.60		399.60
Total galleries account		604.33	604.33
Total			1,003.93
Deduct disallowance			10.00
Total expenditure			993.93
Balance July 1, 1900			1.35

FURNITURE AND FIXTURES, 1899.

Total statement of receipts and expenditures.

RECEIPTS.

Appropriation by Congress July 1, 1898 .... $35,000.00

EXPENDITURES.

	Regular.	Galleries.	Total.
Salaries or compensation	$7,322.37	$5,138.11	$12,460.48
Special services	54.40	4.80	59.20
Total services	7,376.77	5,142.91	12,519.68
Miscellaneous:			
Exhibition cases	2,211.98	8,983.70	11,195.68
Storage cases	175.20		175.20
Drawers, trays, etc	612.49	217.44	829.93
Frames and woodwork	651.97	344.51	996.48
Glass	504.21	3,295.12	3,799.33
Hardware	882.60	928.79	1,811.39
Tools	66.99		66.99
Cloth	151.41	20.20	171.61
Glass jars	251.07		251.07
Lumber	762.50	978.56	1,741.06
Paints, oils, etc	585.44		585.44
Office furniture	293.10	6.10	299.20
Leather and rubber	73.30		73.30
Iron brackets	47.41	34.65	82.06
Apparatus	300.53		300.53
Drawings for cases	36.50	47.00	83.50
Plumbing	16.20		16.20
Total miscellaneous	7,622.90	14,856.07	22,503.97
Total regular appropriation	14,999.67		
Total galleries appropriation		19,998.98	
Total expenditure			34,998.65
Balance July 1, 1900			1.35

NATIONAL MUSEUM—FURNITURE AND FIXTURES, 1898.

Balance as per report July 1, 1899	$1.23

Balance carried, under provisions of section 3090, Revised Statutes, by the Treasury Department to the credit of the surplus fund, June 30, 1900.

NATIONAL MUSEUM—HEATING AND LIGHTING, ETC., 1900.

RECEIPTS.

Appropriation by Congress for the year ending June 30, 1900, "for expense of heating, lighting, electrical, telegraphic, and telephonic service for the National Museum" (sundry civil act, March 3, 1899)	$14,000.00

EXPENDITURES.

Services	$6,676.65		
Special services	8.00		
Total services		$6,684.65	
Miscellaneous:			
Coal and wood	$3,649.09		
Gas	1,125.10		
Rental of call boxes	100.00		
Electrical supplies	545.40		
Electricity	249.77		
Heating supplies	684.53		
Telegrams	16.85		
Telephones	382.65		
Total miscellaneous		6,753.39	
Total expenditures			13,438.04
Balance July 1, 1900			561.96

Analysis of expenditures for salaries or compensation.

Salaries or compensation:		
1 engineer, 12 months, at $115	$1,380.00	
1 fireman, 12 months, at $50	600.00	
1 fireman, 12 months, at $60	720.00	
1 skilled laborer, 9 months 82½ days, at $75	882.50	
1 skilled laborer, 8 months 13 days, at $66.67; 3 months, at $66.66	762.23	
1 skilled laborer, 12 months, at $60	720.00	
1 telephone operator, 10 months 17 days, at $50	527.42	
1 laborer, 235 days, at $1.50	352.50	
1 laborer, 314 days, at $1.50	471.00	
1 laborer, 86 days, at $1.50	129.00	
1 coal passer, 88 days, at $1.50	132.00	
		$6,676.65

NATIONAL MUSEUM—HEATING AND LIGHTING, ETC., 1899.

Balance as per report July 1, 1899	$1,780.02

EXPENDITURES.

Miscellaneous:		
Coal and wood	$1.04	
Gas	110.60	
Rental of call boxes	30.00	
Electrical supplies and motor	818.92	
Heating supplies	298.87	
Telegrams	25.33	
Telephones	495.25	
Total expenditures		$1,780.01
Balance July 1, 1900		.01

HEATING, LIGHTING, ETC., 1899.

Total statement of receipts and expenditures.

RECEIPTS.

Appropriation by Congress, July 1, 1898	$14,000.00

EXPENDITURES.

Salaries or compensation	$6,914.80		
Special services	97.00		
Total services		$7,011.80	
Miscellaneous:			
Coal and wood	$3,320.07		
Gas	1,260.20		
Rental of call boxes	120.00		
Electrical supplies and motor	1,139.35		
Heating supplies	599.27		
Telegrams	41.50		
Travel	12.55		
Telephones	495.25		
Total miscellaneous		6,988.19	
Total expenditures			13,999.99
Balance July 1, 1900			.01

NATIONAL MUSEUM—HEATING AND LIGHTING, ETC., 1898.

Balance as per report July 1, 1899	$5.49

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1900.

NATIONAL MUSEUM—POSTAGE, 1900.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1900, "for postage stamps and foreign postal cards for the National Museum" (sundry civil act, March 3, 1899)	$500.00

EXPENDITURES.

For postage stamps and cards	500.00

NATIONAL MUSEUM—PRINTING AND BINDING, 1900.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1900, "for the Smithsonian Institution, for printing labels and blanks, and for the 'bulletins' and 'proceedings' of the National Museum, the editions of which shall not be less than 3,000 copies, and binding in half turkey, or material not more expensive, scientific books and pamphlets presented to and acquired by the National Museum library" (sundry civil act, March 3, 1899)	$17,000.00

EXPENDITURES.

Bulletins of the Museum	$5,330.83	
Proceedings of the Museum	5,564.61	
Labels	1,944.26	
Blanks	168.00	
Envelopes, pads, circulars	83.53	
Cards	93.72	
Binding	1,556.36	
Congressional Record	32.00	
Total expenditures		14,773.31
Balance July 1, 1900		2,226.69

NATIONAL MUSEUM—RENT OF WORKSHOPS, 1900.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1900, "for rent of workshops and temporary storage quarters for the National Museum" (sundry civil act, March 3, 1899)	$4,040.00

EXPENDITURES.

Rent of workshops and storage quarters:		
No. 431 Ninth street SW	$1,999.92	
No. 217 Seventh street SW	1,080.00	
No. 313 Tenth street SW	600.00	
No. 915 Virginia avenue SW. (rear)	360.00	
Total expenditures		4,039.92
Balance July 1, 1900		.08

NATIONAL MUSEUM—RENT OF WORKSHOPS, 1899.

Balance as per report July 1, 1899	$110.08
Balance July 1, 1900	110.08

NATIONAL MUSEUM—RENT OF WORKSHOPS, 1898.

Balance July 1, 1899, as per last report	$0.08

Balance carried, under the provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1900.

NATIONAL MUSEUM—BUILDING REPAIRS, 1900.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1900, "for repairs to buildings, shops, and sheds, National Museum, including all necessary labor and material" (sundry civil act, March 3, 1899)	$6,000.00

EXPENDITURES.

Salaries or compensation:			
1 carpenter, 6 days, at $3	$18.00		
1 carpenter, 6 days, at $3	18.00		
1 carpenter, 18 days, at $3	54.00		
1 carpenter, 145 days, at $3	435.00		
1 skilled laborer, 2 months 11 days, at $60	141.29		
1 skilled laborer, 104½ days, at $2	209.00		
1 skilled laborer, 234 days, at $2	468.00		
1 skilled laborer, 26 days, at $2	52.00		
1 laborer, 233 days, at $1.25	291.26		
1 laborer, 15 days, at $1.50	22.50		
1 laborer, 16 days, at $1.50	24.00		
1 laborer, 15 days, at $1.50	22.50		
1 laborer, 15 days, at $1.50	22.50		
1 laborer, 15 days, at $1.50	22.50		
1 laborer, 15 days, at $1.50	22.50		
1 laborer, 3½ days, at $1.50	5.25		
1 laborer, 3½ days, at $1.50	5.25		
		$1,833.55	
Miscellaneous:			
Terrazzo floors	2,166.31		
Cement, sand, mortar, lime, gravel, and charcoal	253.45		
Hardware	43.44		
Paints and oils	100.32		
Glass	158.31		
Steel beams and angles	457.23		
Drawings, decorating walls, etc	367.25		
Cloth and paper	19.88		
Doors and molding	260.20		
Lumber	65.06		
Bricks	13.93		
Removing dirt	10.00		
Total miscellaneous		3,915.38	
Total expenditures			5,748.93
Balance July 1, 1900			251.07

NATIONAL MUSEUM—BUILDING REPAIRS, 1899.

Balance as per report July 1, 1899	$81.08

EXPENDITURES.

Special services	$17.00
Miscellaneous:	
Cement	10.55
Glass	15.00
Hardware and tools	8.13

Micellaneous—Continued.		
Brick	$7.50	
Lumber	6.29	
Lime, mortar, sand	15.70	
Total expenditures		$80.17
Balance July 1, 1900		.91

BUILDING REPAIRS, 1899.

Total statement of receipts and expenditures.

RECEIPTS.

Appropriation by Congress July 1, 1898			$4,000.00

EXPENDITURES.

Salaries or compensation	$973.01		
Special services	17.00		
Total services		$990.01	
Miscellaneous:			
Terrazzo and marble floors	1,420.56		
Lumber	545.45		
Woodwork	264.00		
Cement	199.00		
Hardware and tools	172.53		
Mortar, sand, gravel, lime, slate	150.31		
Paints and oils	89.89		
Iron grills	29.60		
Brick	35.85		
Tiles	31.80		
Removing dirt	25.00		
Brushes	10.50		
Blue prints	2.59		
Glass	27.80		
Travel	4.20		
Total miscellaneous		3,009.08	
Total expenditures			3,999.09
Balance July 1, 1900			.91

NATIONAL MUSEUM—BUILDING REPAIRS, 1898.

Balance as per report July 1, 1899	$4.53

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1900.

NATIONAL MUSEUM—GALLERIES, 1899.

Balance as per report July 1, 1899		$4,301.66

EXPENDITURES.

Ironwork	$1,983.88	
Hardware	13.57	
Cement, etc	138.85	

Drawings	$4.00	
Advertising	9.87	
Bricks	7.50	
Woodwork	156.00	
Skylights and ventilators	1,782.20	
Total expenditures		$4,095.87
Balance July 1, 1900		205.79

GALLERIES, 1899.

Total statement of receipts and expenditures.

RECEIPTS.

Appropriation by Congress, July 1, 1898	$10,000.00

EXPENDITURES.

Salaries or compensation	$940.56		
Total salaries		$940.56	
Miscellaneous:			
Ransome arches	1,609.38		
Ironwork	3,322.23		
Terrazzo floor and marble	1,295.09		
Lumber	103.34		
Blue prints and drawings	81.00		
Advertising	61.07		
Hardware and tools	54.56		
Sand, slate, cement, mortar	234.45		
Brick	46.00		
Canvas	29.21		
Paint	25.65		
Travel	23.10		
Sheeting	21.12		
Paper	5.25		
Drawings	4.00		
Woodwork	156.00		
Skylights and ventilators	1,782.20		
Total miscellaneous		8,853.65	
Total expenditures			9,794.21
Balance July 1, 1900			205.79

NATIONAL MUSEUM—GALLERIES, 1898.

Balance as per report July 1, 1899	$8.87

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1900.

NATIONAL MUSEUM—REBUILDING SHEDS, 1898.

Balance as per report July 1, 1899	$0.78

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1900.

NATIONAL MUSEUM—BOOKS, 1900.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1900, "for purchase of books, pamphlets, and periodicals for reference in the National Museum" (sundry civil act, March 3, 1899)	$2,000.00

EXPENDITURES.

For purchase of books, pamphlets, and periodicals from July 1, 1899, to June 30, 1900	1,121.28
Balance July 1, 1900	878.72

NATIONAL MUSEUM—BOOKS, 1899.

Balance, as per report July 1, 1899	$699.57

EXPENDITURES.

For purchase of books, pamphlets, and periodicals from July 1, 1899, to June 30, 1900	674.49
Balance, July 1, 1900	25.08

ASTROPHYSICAL OBSERVATORY, SMITHSONIAN INSTITUTION, 1900.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1900, "for maintenance of Astrophysical Observatory, under the direction of the Smithsonian Institution, including salaries of assistants, the purchase of necessary books and periodicals, apparatus, printing and publishing results of researches, not exceeding one thousand five hundred copies, repairs and alteration of buildings, and miscellaneous expenses, ten thousand dollars" (sundry civil act, March 3, 1899)	$10,000.00

DISBURSEMENTS.

Salaries or compensation:

1 aid, 12 months, at $166.67	$2,000.02
1 junior assistant, 12 months, at $110	1,320.00
1 instrument maker, 10½ months and 26½ days, at $80	$908.39
1 stenographer, 12 months, at $75	900.00
1 clerk, 1 month, at $100	100.00
1 fireman, 12 months, at $45	540.00
1 cleaner, 169 days, at $1	169.00
1 draftsman, 45 hours, at 75 cents	33.75
1 carpenter, 26 days, at $3	78.00
1 carpenter, 13 days, at $3	39.00
1 carpenter, 11 days, at $3	33.00
1 carpenter, 10 days, at $3	30.00
1 painter, 5¾ days, at $3	17.25
1 painter, 1 day, at $2.50	2.50
1 painter, 1 day, at $2	2.00
1 electrician, 17 days, at $2.50	42.50
1 skilled laborer, 5 days, at $75	13.13
1 skilled laborer, 2 days, at $2.25; 2 days, at $60	8.37

Salaries or compensation—Continued.			
1 laborer, 5 days, at $1.50	$7.50		
1 laborer, 2 days, at $1.50	3.00		
1 laborer, 1 day, at $1.50	1.50		
Total salaries or compensation		$6,243.91	
General expenses:			
Apparatus and tools	$926.65		
Books	122.90		
Drawings	41.75		
Freight	18.62		
Castings	190.98		
Fuel	27.30		
Furniture	2.25		
Postage and telegrams	2.37		
Stationery and supplies	382.83		
Traveling expenses	71.33		
Publications	704.03		
Lumber	44.30		
		2,535.31	
Total disbursements			$8,784.22
Balance July 1, 1900			1,215.78

ASTROPHYSICAL OBSERVATORY, 1899.

Balance July 1, 1899, as per last report	$752.36

DISBURSEMENTS.

General expenses:		
Apparatus	$16.90	
Books	71.47	
Freight	8.95	
Lumber	2.90	
Publications	453.30	
Supplies	194.87	
Total disbursements		748.39
Balance July 1, 1900		3.97

ASTROPHYSICAL OBSERVATORY, 1898.

Balance July 1, 1899, as per last report	$0.17

Balance carried, under the provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1900.

OBSERVATION OF ECLIPSE OF MAY 28, 1900.

RECEIPTS.

Appropriation by Congress "for cost of apparatus, transportation of observers and equipment, subsistence, reduction of observations, printing and publishing of results, not exceeding one thousand five hundred copies, and employment of such temporary aid as may be required, including all necessary field and other expenses, four thousand dollars" (deficiency act, February 9, 1900)	$4,000.00

Salaries or compensation:			
1 carpenter, 50½ days, at $3	$151.50		
1 carpenter, 37 days, at $3	111.00		
1 carpenter, 17 days, at $3	51.00		
1 carpenter, ½ day, at $3	1.50		
1 carpenter, ½ day, at $3	1.50		
1 carpenter, ½ day, at $3	1.50		
1 carpenter, ½ day, at $3	1.50		
1 painter, 5 days, at $3	15.00		
1 awning maker, 9 days, at $1.50	13.50		
1 skilled laborer, 23 days, at $60	45.23		
1 seamstress, 7 days, and 1 cleaner, 8 days, at $1	15.00		
Total salaries or compensation		$408.23	
General expenses:			
Apparatus	$682.52		
Buildings	286.00		
Building material	76.92		
Castings	19.65		
Freight and hauling	28.65		
Lumber	97.87		
Rental	190.00		
Supplies	183.88		
Traveling expenses	497.08		
		2,062.57	
Total disbursements			$2,470.80
Balance July 1, 1900			1,529.20

NATIONAL ZOOLOGICAL PARK, 1900.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1900, "for continuing the construction of roads, walks, bridges, water supply, sewerage, and drainage; and for grading, planting, and otherwise improving the grounds; erecting and repairing buildings and inclosures; care, subsistence, purchase, and transportation of animals, including salaries or compensation of all necessary employés, the purchase of necessary books and periodicals, and general incidental expenses not otherwise provided for, seventy-five thousand dollars; one-half of which sum shall be paid from the revenues of the District of Columbia and the other half from the Treasury of the United States; and of the sum hereby appropriated five thousand dollars shall be used for continuing the entrance into the Zoological Park from Woodley Lane and opening driveway into Zoological Park from said entrance along the bank of Rock Creek, and five thousand dollars shall be expended in widening the Adams Mill Road entrance to the Zoological Park from the corner of Eighteenth street and Columbia road, by acquiring by purchase or condemnation of land sufficient to widen the same to a width of one hundred feet, and such road, so widened, shall form a parkway under the control of the Zoological Park" (sundry civil act, March 3, 1899) $75,000.00

DISBURSEMENTS.

Salaries or compensation:	
1 superintendent, 12 months, at $225	$2,700.00
1 property clerk, 12 months, at $125	1,500.00
1 clerk, 6 months, at $75; 6 months, at $90	990.00
1 stenographer, 12 months, at $62.50	750.00
1 copyist, 3 days, at $1.50	4.50
1 copyist, 12 months, at $75	900.00
1 copyist, 2 months and 21 days, at $50	135.00
1 head keeper, 12 months, at $100	1,200.00
1 keeper, 1 month, at $75	75.00
1 keeper, 12 months, at $60	720.00
1 keeper, 12 months, at $60	720.00
1 keeper, 12 months, at $60	720.00
1 keeper, 11 months, at $60	660.00
1 landscape gardener, 12 months, at $75	900.00
1 assistant foreman, 12 months, at $60	720.00
1 watchman, 12 months, at $60	720.00
1 watchman, 4 months, at $50; 6 months, at $60	680.00
1 watchman, 12 months, at $50	600.00
1 blacksmith, 12 months, at $75	900.00
1 assistant blacksmith, 12 months, at $60	720.00
1 workman, 12 months, at $60	720.00
1 workman, 12 months, at $50	600.00
1 workman, 33½ days, at $50	54.62
1 laborer, 6 months, at $50; 6 months, at $60	660.00
1 laborer, 12 months, at $50	600.00
1 laborer, 11½ months, at $50	575.00
1 laborer, 3 months and 4 days, at $50	156.45
1 laborer, 3½ months, at $45; 8 months, at $50	557.50
1 laborer, 9½ months and 9 days, at $20	195.81
Total salaries or compensation	20,433.88
Miscellaneous:	
Buildings	1,114.03
Building material	143.20
Fencing, cage material, etc	1,417.13
Food	7,239.86
Freight	618.12
Furniture	33.00
Illustrations	75.00
Fuel	638.81
Lumber	1,198.83
Machinery, tools, etc	565.84
Miscellaneous	910.15
Paints, oils, glass, etc	77.85
Postage and telegraph	100.98
Purchase of animals	420.75
Road material and grading	2,603.50
Special services	549.99
Stationery, books, etc	293.55
Surveying, plans, etc	85.00
Traveling and field expenses	265.13

Miscellaneous—Continued.

Trees, plants, etc	$426.70
Water supply, sewerage, etc	504.02
Total miscellaneous	19,281.44

Wages of mechanics and laborers and hire of teams in constructing buildings and inclosures, laying water pipes, building roads, gutters, and walks, planting trees, and otherwise improving the grounds:

1 laborer, 34¼ days, at $1	34.25
1 laborer, 1½ days, at $1	1.50
1 laborer, 12½ days, at $1	12.50
1 laborer, 12 days, at $1	12.00
1 stonebreaker, 15½ cubic yards, at 60 cents	42.60
laborer, 33 days, at $1	
1 attendant, 101 days, at 75 cents	294.25
laborer, 218½ days, at $1	
1 attendant, 102 days, at 75 cents	156.25
laborer, 79¾ days, at $1	
1 laborer, 123 days, at $1; 242½ days, at $1.25	426.13
1 laborer, 24½ days, at $1.25; 225¾ days, at $1.50	369.24
1 laborer, 1 day, at $1.25	1.25
1 water boy, 113¾ days, at 75 cents	274.87
attendant, 28¾ days, at 75 cents	
laborer, 140½ days, at $1	
laborer, 22 days, at $1.25	
1 laborer, 20¾ days, at $1.25	25.94
1 laborer, 12 days, at $1.25	15.00
1 laborer, 7¼ days, at $1.25; 19 days, at $1.50	37.56
1 laborer, 2½ days, at $1.25	3.12
1 laborer, 26 days, at $1.25	32.50
1 laborer, 2½ days, at $1.25	3.12
1 laborer, 1 day, at $1.25	1.25
1 laborer, 17 days, at $1.25	21.25
1 laborer, 100¼ days, at $1.25; 104 days, at $1.50	281.32
1 laborer, 18½ days, at $1.25	23.12
1 laborer, 20½ days, at $1.25	25.62
1 laborer, 19¼ days, at $1.25	24.06
1 laborer, 7¼ days, at $1.25	9.06
1 laborer, 7¼ days, at $1.25; 21½ days, at $1.50	41.31
1 laborer, 49 days, at $1.50	73.50
1 laborer, 7 days, at $1.50	10.50
1 laborer, 315¾ days, at $1.50	473.65
1 laborer, 63¾ days, at $1.50	95.62
1 laborer, 2 days, at $1.50	3.00
1 laborer, 14 days, at $1.50	21.00
1 laborer, 264 days, at $1.50	396.00
1 laborer, 123¼ days, at $1.50	184.87
1 laborer, 112½ days, at $1.50	168.75
1 laborer, 139 days, at $1.50	208.49
1 laborer, 142½ days, at $1.50	214.76
1 laborer, 35 days, at $1.50	52.51
1 laborer, 284½ days, at $1.50	426.74
1 laborer, 272⅔ days, at $1.50	409.01
1 laborer, 2 days, at $1.50	3.00

Wages of mechanics, laborers, etc.—Continued.

1 laborer, 9 days, at $1.50	$13.50
1 laborer, 7 days, at $1.50	10.50
1 laborer, 206¾ days, at $1.50	310.14
1 laborer, 7 days, at $1.50	10.50
1 laborer, 365 days, at $1.50	547.50
1 laborer, 11 days, at $1.50	16.50
1 laborer, 22¾ days, at $1.50 painter, 20¾ days, at $3	96.38
1 laborer, 139 days, at $1.50	208.50
1 laborer, 1¼ days, at $1.50	1.87
1 laborer, 12 days, at $1.50	18.00
1 laborer, 126½ days, at $1.50	189.74
1 laborer, 2 days, at $1.50	3.00
1 laborer, 15 days, at $1.50	22.50
1 laborer, 82½ days, at $1.50	123.75
1 laborer, 104¾ days, at $1.50	157.13
1 laborer, 378¾ days, at $1.50	568.13
1 laborer, 364¾ days, at $1.50	547.13
1 laborer, 35 days, at $1.50	52.50
1 laborer, 64½ days, at $1.50	96.75
1 laborer, 74 days, at $1.50	111.00
1 laborer, 256¼ days, at $1.50	384.39
1 laborer, 2 days, at $1.50	3.00
1 laborer, 296¼ days, at $1.50	444.37
1 laborer, 366¼ days, at $1.50	549.37
1 laborer, 185¾ days, at $1.50	278.62
1 laborer, 13 days, at $1.50	19.50
1 laborer, 6 days, at $1.50	9.00
1 laborer, 263½ days, at $1.50	395.25
1 laborer, 10 days, at $1.50	15.00
1 laborer, 159 days, at $1.50	238.49
1 laborer, 11 days, at $1.50	16.50
1 laborer, 22 days, at $1.50	33.00
1 laborer, 22½ days, at $1.50	33.75
1 laborer, 370¼ days, at $1.50	555.38
1 laborer, 180 days, at $1.50	270.03
1 laborer, 280¼ days, at $1.50	420.36
1 laborer, 25¼ days, at $1.50	37.88
1 laborer, 15½ days, at $1.50	23.25
1 laborer, 259 days, at $1.50	388.50
1 laborer, 240¾ days, at $1.50	361.12
1 laborer, 365 days, at $1.50	547.50
1 laborer, 21½ days, at $1.50	32.25
1 laborer, 61 days, at $1.50; 83 days, at $1.75	236.75
1 laborer, 264¾ days, at $2	529.50
1 laborer, 365½ days, at $2	731.00
1 laborer, 13 days, at $2	26.00
1 laborer, 138 days, at $2.50	345.63
1 laborer, 9 days, at $2.50	22.50
1 laborer, 365 days, at $2.50	912.50
1 water boy, 78 days, at 50 cents	39.00
1 water boy, 10¼ days, at 50 cents	5.13
1 water boy, 10 days, at 50 cents	5.00
1 water boy, 18 days, at 50 cents	9.00
1 water boy, 36 days, at 75 cents	27.00

Wages of mechanics, laborers, etc.—Continued.

1 water boy, 13 days, at 50 cents	$6.50	
1 water boy, 1½ days, at 50 cents	.75	
1 water boy, 35 days, at 50 cents	17.50	
1 water boy, 19 days, at 50 cents	9.50	
1 water boy, 1 day, at 50 cents	.50	
1 water boy, 21 days, at 50 cents; 39½ days, at 75 cents.	40.13	
1 attendant, 176½ days, at 75 cents water boy, 171¼ days, at 75 cents	260.82	
1 attendant, 10 days, at 75 cents	7.50	
1 attendant, 222 days, at 75 cents	166.50	
1 attendant, 57 days, at 75 cents	42.75	
1 attendant, 15 days, at 75 cents	11.25	
1 attendant, 2 days, at 75 cents	1.50	
1 attendant, 2 days, at 75 cents	1.50	
1 attendant, 365 days, at 75 cents	273.75	
1 weeder, 53 days, at 50 cents	26.50	
1 weeder, 58¾ days, at 50 cents	29.38	
1 stonebreaker, 10 cubic yards, at 60 cents	6.00	
1 stonebreaker, 86 cubic yards, at 60 cents	51.60	
1 stonebreaker, 28½ cubic yards, at 60 cents	17.10	
1 stonebreaker, 35½ cubic yards, at 60 cents	21.30	
1 carpenter, 18 days, at $3	54.00	
1 carpenter, 15 days, at $3	45.00	
1 carpenter, 12 days, at $3	36.00	
1 carpenter, 6 days, at $3	18.00	
1 carpenter, 12 days, at $2.50	30.00	
1 carpenter, 307¾ days, at $3	923.25	
1 carpenter, 10 days, at $3	30.00	
1 carpenter, 11½ days, at $3	34.50	
1 carpenter, 25⅛ days, at $3	75.38	
1 carpenter, 25⅛ days, at $3	75.38	
1 carpenter, 26 days, at $3	78.00	
1 carpenter, 14¾ days, at $3	44.25	
1 carpenter, 21¾ days, at $2.80	60.90	
1 paver, 1¼ days, at $3	3.75	
1 blacksmith, 10¼ days, at $2.50	25.62	
1 workman, 365 days, at $1.75	638.75	
1 wagon and team, 85 days, at $3	255.00	
1 wagon and team, 120¾ days, at $3	362.25	
1 wagon and team, 19¾ days, at $3	59.25	
1 wagon and team, 12½ days, at $3	37.50	
1 horse and cart, 8¼ days, at $1.50	12.37	
1 horse and cart, 58½ days, at $1.50	87.75	
1 horse and cart, 146¼ days, at $1.50	219.37	
1 horse and cart, 21 days, at $1.50	31.50	
1 horse and cart, 6 days, at $1.50	9.00	
1 horse and cart, 7 days, at $1.50	10.50	
1 horse and cart, 2 days, at $1.50	3.00	
1 horse and cart, 27½ days, at $1.50	41.25	
1 horse, 246¾ days, at 50 cents	123.36	
Total wages of mechanics, etc	20,377.22	
Total disbursements		$60,092.54
Balance July 1, 1900		14,907.46

NATIONAL ZOOLOGICAL PARK, 1899.

Balance July 1, 1899, as per last report		$3,800.10

DISBURSEMENTS.

General expenses:		
Animals	$118.95	
Buildings	700.90	
Building material	61.83	
Fencing and cage material	41.29	
Food	596.50	
Freight and hauling	322.98	
Fuel	16.38	
Lumber	238.60	
Machinery, tools, etc	20.32	
Miscellaneous	95.78	
Paints, oils, glass	88.84	
Postage and telegraph	151.19	
Illustrations	53.90	
Road material and grading	88.94	
Stationery, books, etc	338.98	
Traveling expenses	43.57	
Surveying, plans, etc	411.00	
Trees, plants, etc	89.14	
Water supply, sewerage, etc	239.20	
Total disbursements		$3,718.29
Balance July 1, 1900		81.81

NATIONAL ZOOLOGICAL PARK, 1898.

Balance July 1, 1899, as per last report	$7.17

DISBURSEMENTS.

General expenses:	
Postage and telegraph	.65
Balance	6.50

Balance carried, under the provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1900.

RECAPITULATION.

The total amount of funds administered by the Institution during the year ending June 30, 1900, appears from the foregoing statements and the account books to have been as follows:

SMITHSONIAN INSTITUTION.

From balance of last year, July 1, 1899	$74,703.42	
From interest on Smithsonian fund for the year	54,720.00	
From interest on West Shore bonds	1,680.00	
From sales of publications	277.84	
From repayments of freight, etc	4,131.97	
		$135,513.23

APPROPRIATIONS COMMITTED BY CONGRESS TO THE CARE OF THE INSTITUTION.

International exchanges—Smithsonian Institution:		
From balance of 1897–98	6.11	
From balance of 1898–99	1,829.33	
From appropriation for 1899–1900	24,000.00	
		25,835.44

American Ethnology—Smithsonian Institution:		
From balance of 1897–98	$35.36	
From balance of 1898–99	3,035.00	
From appropriation for 1899–1900	50,000.00	
		$53,070.36
Preservation of collections—National Museum:		
From balance of 1897–98	97.28	
From balance of 1898–99	4,661.94	
From appropriation for 1899–1900	170,000.00	
		174,759.22
Furniture and fixtures—National Museum:		
From balance of 1897–98	1.23	
From balance of 1898–99	995.28	
From appropriation for 1899–1900	25,000.00	
		25,996.51
Heating and lighting, etc.—National Museum:		
From balance of 1897–98	5.49	
From balance of 1898–99	1,780.02	
From appropriation for 1899–1900	14,000.00	
		15,785.51
Printing—National Museum:		
From appropriation for 1899–1900		17,000.00
Rent of workshops, etc.—National Museum:		
From balance of 1897–98	.08	
From balance of 1898–99	110.08	
From appropriation for 1899–1900	4,040.00	
		4,150.16
Postage—National Museum:		
From appropriation for 1899–1900		500.00
Books—National Museum:		
From appropriation for 1899–1900		2,000.00
Building repairs—National Museum:		
From balance of 1897–98	4.53	
From balance of 1898–99	81.08	
From appropriation for 1899–1900	6,000.00	
		6,085.61
Galleries—National Museum:		
From balance for 1897–98	8.87	
From balance for 1898–99	4,301.66	
		4,310.53
Rebuilding sheds, etc.—National Museum:		
From appropriation for 1898–99		.78
Astrophysical Observatory—Smithsonian Institution:		
From balance of 1897–98	.17	
From balance of 1898–99	752.36	
From appropriation for 1899–1900	10,000.00	
		10,752.53
Observation of eclipse of May 28, 1900:		
From appropriation		4,000.00
National Zoological Park:		
From balance of 1897–98	7.15	
From balance of 1898–99	3,800.10	
From appropriation for 1899–1900	75,000.00	
		78,807.25

SUMMARY.

Smithsonian Institution	$135,513.23	
Exchanges	25,835.44	
Ethnology	53,070.36	
Preservation of collections	174,759.22	
Furniture and fixtures	25,996.51	
Heating and lighting	15,785.51	
Printing	17,000.00	
Rent of workshop	4,150.16	
Postage	500.00	
Books	2,000.00	
Building repairs	6,085.61	
Galleries	4,310.53	
Rebuilding sheds	.78	
Astrophysical Observatory	10,752.53	
Observation of eclipse of May 28, 1900	4,000.00	
National Zoological Park	78,807.25	
		$558,567.13

The committee has examined the vouchers for payment from the Smithsonian income during the year ending June 30, 1900, each of which bears the approval of the Secretary, or, in his absence, of the acting secretary, and a certificate that the materials and services charged were applied to the purposes of the Institution.

The committee has also examined the accounts of the several appropriations committed by Congress to the Institution, and finds that the balances hereinbefore given correspond with the certificates of the disbursing clerk of the Smithsonian Institution, whose appointment as such disbursing officer has been accepted and his bond approved by the Secretary of the Treasury.

The quarterly accounts current, the vouchers, and journals have been examined and found correct.

Statement of regular income from the Smithsonian fund available for use in the year ending June 30, 1901.

Balance July 1, 1900		$76,219.07
(Including cash from executors of J. H. Kidder)	$5,000.00	
(Including cash from Dr. Alex. Graham Bell)	5,000.00	
	10,000.00	
Interest due and receivable July 1, 1900	27,360.00	
Interest due and receivable January 1, 1901	27,360.00	
Interest, West Shore Railroad bonds, due July 1, 1900	840.00	
Interest, West Shore Railroad bonds, due January 1, 1901	840.00	
		56,400.00
Total available for year ending June 30, 1901		132,619.07

Respectfully submitted.

J. B. HENDERSON,
ALEXANDER GRAHAM BELL,
Executive Committee.

WASHINGTON, D. C., *January 16, 1901.*

ACTS AND RESOLUTIONS OF CONGRESS RELATIVE TO THE SMITHSONIAN INSTITUTION, NATIONAL MUSEUM, ETC.

(Continued from previous reports.)

[Fifty-sixth Congress, first session.]

SMITHSONIAN INSTITUTION.

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the vacancy in the Board of Regents of the Smithsonian Institution, of the class other than Members of Congress, caused by the death of William Preston Johnston, of Louisiana, shall be filled by the appointment of Richard Olney, a resident of Massachusetts. (Approved, January 24, 1900; Statutes, XXXI, 709.)

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the vacancy in the Board of Regents of the Smithsonian Institution, of the class other than Members of Congress, shall be filled by the reappointment of Andrew D. White, a resident of the State of New York, whose term of office has expired. (Approved, June 2, 1900; Statutes, XXXI, 718.)

Resolved by the Senate (the House of Representatives concurring), That there be printed of "The Smithsonian Institution: Documents relative to its Origin and History," seven thousand copies, of which fifteen hundred copies shall be for the use of the Senate, three thousand copies for the use of the House of Representatives, and two thousand five hundred copies for the use of the Smithsonian Institution. (Passed Senate April 26, 1900; passed House May 11, 1900. Statutes, XXXI, 10, concurrent resolutions.)

SMITHSONIAN DEPOSIT [LIBRARY OF CONGRESS]: For custodian, one thousand five hundred dollars; one assistant, one thousand two hundred dollars; one messenger, seven hundred and twenty dollars; one messenger boy, three hundred and sixty dollars; in all, three thousand seven hundred and eighty dollars. (Legislative, executive, and judicial act for 1901, approved April 17, 1900; Statutes, XXXI, 95.)

INTERNATIONAL EXCHANGES.

For expenses of the system of international exchanges between the United States and foreign countries, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees, and the purchase of necessary books and periodicals, twenty-four thousand dollars. (Sundry civil act for 1901, approved June 6, 1900; Statutes, XXXI, 602.)

NATIONAL MUSEUM.

For cases, furniture, fixtures, and appliances required for the exhibition and safe-keeping of the collections of the National Museum, including two thousand five hundred dollars for furnishing new lecture room and including salaries or compensation of all necessary employees, seventeen thousand five hundred dollars.

For expense of heating, lighting, electrical, telegraphic, and telephonic service for the National Museum, including three thousand five hundred dollars for electric installation, seventeen thousand five hundred dollars.

For continuing the preservation, exhibition, and increase of the collections from the surveying and exploring expeditions of the Government, and from other sources, including salaries or compensation of all necessary employees, one hundred and eighty thousand dollars, of which sum five thousand five hundred dollars may be used for necessary drawings and illustrations for publications of the National Museum; and all other necessary incidental expenses.

For purchase of specimens to supply deficiencies in the collections of the National Museum, ten thousand dollars.

For purchase of books, pamphlets, and periodicals for reference in the National Museum, two thousand dollars.

For repairs to buildings, shops, and sheds, National Museum, including repairs of roof, and for all necessary labor and material, fifteen thousand dollars.

For rent of workshops and temporary storage quarters for the National Museum, four thousand and forty dollars.

For postage stamps and foreign postal cards for the National Museum, five hundred dollars. (Sundry civil act for 1901, approved June 6, 1900; Statutes, XXXI, 602.)

Printing and binding: For the Smithsonian Institution, for printing labels and blanks, and for the "Bulletins" and "Proceedings" of the National Museum, the editions of which shall not be less than three thousand copies, and binding, in half turkey, or material not more expensive, scientific books and pamphlets presented to and acquired by the National Museum Library, seventeen thousand dollars. (Sundry civil act for 1901, approved June 6, 1900; Statutes, XXXI, 643.)

BUREAU OF AMERICAN ETHNOLOGY.

For continuing ethnological researches among the American Indians, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees and the purchase of necessary books and periodicals, fifty thousand dollars, of which sum not exceeding one thousand five hundred dollars may be used for rent of building. (Sundry civil act for 1901, approved June 6, 1900; Statutes, XXXI, 602.)

To pay amounts found due by the accounting officers of the Treasury on account of the appropriation "American Ethnology, Smithsonian Institution," for the fiscal year eighteen hundred and ninety-eight, thirty-four dollars and ninety-one cents. (Deficiency act for 1900, approved June 6, 1900; Statutes, XXXI, 286.)

Resolved by the House of Representatives (*the Senate concurring*), That there be printed at the Government Printing Office eight thousand copies of any matter furnished by the Director of the Bureau of American Ethnology relating to researches and discoveries connected with the study of the American aborigines, the same to be issued as bulletins uniform with the annual reports, one thousand five hundred of which shall be for the use of the Senate, three thousand for the use of the House of Representatives, and three thousand five hundred for distribution by the Bureau. (Passed House April 7, 1900; passed Senate April 27, 1900; Statutes, XXXI, 10, concurrent resolutions.)

ASTROPHYSICAL OBSERVATORY.

For maintenance of Astrophysical Observatory, under the direction of the Smithsonian Institution, including salaries of assistants, the purchase of necessary books and periodicals, apparatus, printing and publishing results of researches, not exceeding one thousand five hundred copies, repairs and alterations of buildings and miscellaneous expenses, twelve thousand dollars. (Sundry civil act for 1901, approved June 6, 1900; Statutes, XXXI, 602.)

Observation of eclipse of May twenty-eighth, nineteen hundred: For cost of apparatus, transportation of observers and equipment, subsistence, reduction of observations, printing and publishing of results, not exceeding one thousand five hundred copies, and employment of such temporary aid as may be required, including all necessary field and other expenses, four thousand dollars. (Urgent deficiency act for 1900, approved February 9, 1900; Statutes, XXXI, 11.)

NATIONAL ZOOLOGICAL PARK.

For continuing the construction of roads, walks, bridges, water supply, sewerage and drainage; and for grading, planting, and otherwise improving the grounds; erecting and repairing buildings and inclosures; care, subsistence, purchase, and transportation of animals, including salaries or compensation of all necessary employees; the purchase of necessary books and periodicals, and general incidental expenses not otherwise provided for, seventy-five thousand dollars;

one-half of which sum shall be paid from the revenues of the District of Columbia and the other half from the Treasury of the United States; and of the sum hereby appropriated five thousand dollars shall be used for continuing the entrance into the Zoological Park from Cathedral avenue and opening driveway into Zoological Park, including necessary grading and removal of earth: *Provided*, That the unexpended balance of the amounts, aggregating eight thousand dollars, heretofore appropriated for widening, grading, and regulating Adams Mill road from Columbia road to the Zoological Park entrance is hereby reappropriated, to be expended under the direction of the Commissioners of the District of Columbia; and that the control of Adams Mill road is hereby vested in the said Commissioners, and all proceedings necessary to purchase or condemn the land necessary to widen said road as authorized by Act approved March third, eighteen hundred and ninety-nine, providing for sundry civil expenses of the Government for the fiscal year ending June thirtieth, nineteen hundred, and for other purposes, shall be taken by said Commissioners.

For construction of a bridge across Rock Creek on the line of the roadway from Quarry road entrance, under the direction of the Engineer Commissioner of the District of Columbia, twenty-two thousand dollars, one-half of which sum shall be paid out of the revenues of the District of Columbia. (Sundry civil act for 1901, approved June 6, 1900; Statutes, XXXI, 603.)

The Secretary of the Smithsonian Institution is hereby authorized to reimburse in the amount of two hundred and seven dollars and seventy-three cents, from the appropriation "National Zoological Park, nineteen hundred," the official account of John W. Morse, assistant paymaster, United States Navy, for expenditures incurred in the purchase, care, and forwarding of a collection of live animals for the National Zoological Park during the fiscal year ending June thirtieth, eighteen hundred and ninety-nine. (Deficiency act for 1900, approved June 6, 1900; Statutes, XXXI, 286.)

For grading and regulating Cathedral avenue from Connecticut avenue to Woodley road and the highway along the west border of the Zoological Park from Woodley road to Cathedral avenue, as shown on the plan of the permanent system of highways, third section, twenty-one thousand dollars: *Provided*, That parties interested first deposit with the collector of taxes of the District of Columbia an equal sum to be used toward defraying the cost of the work: *And provided*, That the full width of the highway bordering the Zoological Park be donated to the District of Columbia whenever it lies within the limits of Woodley Park.

And the Commissioners of the District of Columbia are hereby authorized to use as a highway so much of the Zoological Park as lies within the lines of said proposed highway.

To construct a masonry retaining wall between Cincinnati street and Woodley road to define the limits of a new driveway which the Commissioners of the District of Columbia are hereby authorized to lay out along the east side of Rock Creek from Connecticut avenue to Zoological Park, four thousand dollars: *Provided*, That all the land within the limits of said highway between Cincinnati street and Woodley road shall first be dedicated to the District of Columbia. (District of Columbia act for 1901, approved June 6, 1900; Statutes, XXXI, 561.)

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the sum of ten thousand dollars, or so much thereof as may be necessary, be, and the same is hereby, appropriated, out of any money in the Treasury not otherwise appropriated, for the repair of county roads and bridges (including those in the Rock Creek and the Zoological parks) that were damaged by the storm of June second, nineteen hundred, the same to be immediately available, and to be expended under the Commissioners of the District of Columbia. (Approved, June 7, 1900; Statutes, XXXI, 722.)

The Chief of Engineers of the United States Army is authorized to make an examination and to report to Congress on the first Monday in December, nineteen hundred, plans for the treatment of that section of the District of Columbia situated south of Pennsylvania avenue and north of B street southwest, and for a suitable connection between the Potomac and the Zoological parks, and in making such examinations and plans he is authorized to employ a landscape architect of conspicuous ability in his profession: for services and expenses incident to said examination and report the sum of four thousand dollars is hereby appropriated. (Sundry civil act for 1901, approved June 6, 1900; Statutes, XXXI, 622.)

AMERICAN HISTORICAL ASSOCIATION.

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That there be printed of the annual reports of the American Historical Association, beginning with the report of the year eighteen hundred and ninety-nine, two thousand five hundred copies in addition to those provided for under existing law, of which five hundred copies shall be for the use of the Senate, one thousand copies for the use of the House of Representatives, and one thousand copies for the use of the American Historical Association. (Approved, May 25, 1900; Statutes, XXXI, 717.)

PARIS EXPOSITION.

For each and every purpose named in the paragraph in the sundry civil appropriation Act, approved July first, eighteen hundred and ninety-eight, under the heading "Paris Exposition," one hundred and sixty-nine thousand five hundred dollars, of which amount not exceeding ninety-six thousand five hundred dollars may be expended for buildings and appurtenances, including fire protection, pier landings, approaches, and other construction; not exceeding fifteen thousand dollars may be expended for an exhibit of negro education and industry, and not exceeding twenty thousand dollars may be used for contingent expenses of the commissioner-general, to be expended in his discretion and audited on his certificate; and the limit of the appropriations provided for in said paragraph, as amended by the sundry civil appropriation Act approved March third, eighteen hundred and ninety-nine, is hereby extended to one million one hundred and nineteen thousand five hundred dollars; the appropriation hereby made to be available until expended: *Provided*, That the Commissioner of Patents is authorized and directed to allow such patent models as have been previously exhibited at any international exposition as the Secretary of the Interior may select, to be transported to and from and exhibited at said exposition in the custody of an employee of the Patent Office duly designated for that purpose by the Commissioner of Patents; such models to be returned to the Patent Office at the close of the exposition; but no models shall be removed concerning which litigation is now pending.

For six additional commissioners, to be appointed as provided by the sundry civil appropriation Act, approved July first, eighteen hundred and ninety-eight, who shall perform the duties and be subject to the limitations prescribed therein, at three thousand dollars each, eighteen thousand dollars. (Urgent deficiency act for 1900, approved February 9, 1900; Statutes, XXXI, 24.)

NEW YORK PRINTING EXPOSITION.

JOINT RESOLUTION Authorizing the exhibit of Government relics at the New York Printing Exposition from May second to June second, nineteen hundred.

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of the Treasury be, and he is hereby, authorized in his discretion to exhibit at the New York Printing Exposition from May second to June second, nineteen hundred, a geometrical scroll machine, and such other articles now in the Bureau of Engraving and Printing; also "a picture of Governor William Allen, of Ohio, on a saw blade," now in the possession of the Secret Service Division of the Treasury Department; also copies of charts of Hell Gate, the Battery, and other New York City points, to be printed from original copperplates now in the possession of the Coast and Geodetic Survey, and such other articles in said bureaus as may be of interest to the printing trades.

SEC. 2. That the Secretary of War be, and he is hereby, authorized in his discretion to exhibit at said exposition medical catalogues, old volumes, works in Russian and other foreign tongues, now in the possession of the Surgeon-General of the Army; also samples of work and manuscripts written on stumps, and so forth, by generals in the war of the rebellion, now in the possession of the Rebellion Records Division of the War Department, and such other articles as may be of interest to the printing trades.

SEC. 3. That the Secretary of the Interior be, and he is hereby, authorized in his discretion to exhibit at said exposition such general exhibit of patents as may be of interest to the printing trades.

SEC. 4. That the secretary of the Smithsonian Institution be, and he is hereby, authorized in his discretion to exhibit at said exposition the old Ben Franklin printing press and such other articles now in the National Museum as may be of interest to the printing trades.

SEC. 5. That all expenses incurred in carrying out the provisions of this joint resolution shall be paid by the directors of the New York Printing Exposition, under such regulations as shall be adopted by the Secretary of the Treasury, the Secretary of War, the Secretary of the Interior, and the secretary of the Smithsonian Institution. (Approved, April 23, 1900; Statutes, XXXI, p. 714.)

LOUISIANA PURCHASE EXPOSITION.

For defraying the expenses of the Louisiana Purchase Exposition Commission, when appointed, ten thousand dollars; and when the Louisiana Purchase Exposition of nineteen hundred and three, a corporation under the laws of the State of Missouri, shall have raised, to the satisfaction of the Secretary of the Treasury, ten million dollars for and on account of inaugurating and carrying forward an exposition at Saint Louis, Missouri, to celebrate the one hundredth anniversary of the purchase of Louisiana Territory by the United States, then the United States will authorize the expenditure of the sum of five million dollars for such exposition, to be disbursed under the direction of "The Louisiana Purchase Exposition of nineteen hundred and three," under rules and regulations and under conditions to be hereafter prescribed by the Congress: *Provided, however,* That said sum of five million dollars shall not be expended until the said sum of ten million dollars raised by said Louisiana Purchase Exposition of nineteen hundred and three shall have been expended for and on account of said exposition, and there shall be repaid into the Treasury of the United States the same proportionate amount of the aid given by the United States as shall be repaid to either the corporation or the city of Saint Louis: *And provided further,* That all sums expended by the Government on account of said exposition, except for its own buildings and exhibits and the care of the same, shall be deducted from any general appropriation made for said exposition. (Sundry civil act for 1901, approved June 6, 1900; Statutes, XXXI, p. 644.)

REPORT

OF

S. P. LANGLEY,

SECRETARY OF THE SMITHSONIAN INSTITUTION,

FOR THE YEAR ENDING JUNE 30, 1900.

To the Board of Regents of the Smithsonian Institution.

GENTLEMEN: I have the honor to present herewith my report showing the operations of the Institution during the year ending June 30, 1900, including the work placed under its direction by Congress, in the United States National Museum, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, and the Astrophysical Observatory.

Following the precedent of several years, I have given, in the body of this report, a general account of the affairs of the Institution and its bureaus, while the appendix presents more detailed statements by the persons in direct charge of the different branches of the work. Independently of this the operations of the National Museum are fully treated in a separate volume of the Smithsonian Report, and the Report of the Bureau of American Ethnology constitutes a volume prepared under the supervision of the Director of that Bureau.

THE SMITHSONIAN INSTITUTION.

THE ESTABLISHMENT.

By act of Congress approved August 10, 1846, the Smithsonian Institution was created an "Establishment." Its statutory members are the President, the Vice-President, the Chief Justice of the United States, and the heads of the Executive Departments. The prerogative of the Establishment is the "supervision of the affairs of the Institution and the advice and instruction of the Board of Regents."

A vacancy in the membership of the Establishment, caused by the death of Vice-President Hobart on November 21, 1899, will remain till March 4, 1901.

The Hon. Russell A. Alger resigned as Secretary of War, and was succeeded by the Hon. Elihu Root.

As organized on June 30, 1900, the Establishment consisted of the following ex officio members:

William McKinley, *President of the United States.*
(Vacancy), *Vice-President of the United States.*
Melville W. Fuller, *Chief Justice of the United States.*
John Hay, *Secretary of State.*
Lyman J. Gage, *Secretary of the Treasury.*
Elihu Root, *Secretary of War.*
John W. Griggs, *Attorney-General.*
Charles Emory Smith, *Postmaster-General.*
John D. Long, *Secretary of the Navy.*
Ethan Allen Hitchcock, *Secretary of the Interior.*
James Wilson, *Secretary of Agriculture.*

BOARD OF REGENTS.

The Board consists of the Vice-President and the Chief Justice of the United States as ex officio members, three members of the Senate, three members of the House of Representatives, and six citizens, "two of whom shall be resident in the city of Washington and the other four shall be inhabitants of some State, but no two of them of the same State."

In accordance with a resolution of the Board of Regents adopted January 8, 1890, by which its annual meeting occurs on the fourth Wednesday of each year, the Board met on January 24, 1900, at 10 o'clock a. m.

The following is an abstract of its proceedings, which will be found in fuller detail in the annual report of the Board to Congress, though reference is made later on in this report to several matters upon which action was taken at that meeting.

The Secretary announced the death of Dr. William Preston Johnston, and Senator Platt announced that of Vice-President Hobart. The action taken by the Board will be found under the head of "Necrology."

The Hon. William P. Frye, President pro tempore of the Senate, was present, in accordance with custom, in place of Vice-President Hobart, deceased. On January 4, 1900, the Speaker of the House appointed Representatives R. R. Hitt and Robert Adams, jr., to succeed themselves and Representative Hugh A. Dinsmore to succeed Gen. Joseph Wheeler.

The Secretary presented his report of the operations of the Institution for the fiscal year ending June 30, 1899, and said that the past year had brought many evidences of the continued esteem in which the Institution was held at home and abroad. It was certainly at the present moment better known in Europe than in any previous period of its history.

After the reports of the executive and permanent committees, presented by their chairman, Senator Henderson, had been adopted, the Secretary stated that, owing to other business which was to come before the meeting, he would abridge his usual statement. He then spoke briefly of the National Museum, of the cooperation of the State, War, and Navy Departments for increasing the collections of the National Zoological Park, of the exemption by the President from the rules of the civil service of the Assistant Secretary of the Smithsonian Institution, in charge of the National Museum, and one private secretary or confidential clerk to the Secretary of the Institution, as well as the waiving of competitive examinations for positions on the scientific staff, and of other matters. He further referred to the fact that he was continuing, with the sanction of the Regents, some experiments for the Board of Ordnance and Fortification which were likely to take up considerable time, and he desired to repeat that the Secretary's time, which was partly given in his private hours, was all without charge to the War Department.

The Secretary added that he had intended to bring before the Board specific statements as to the position of the Smithsonian fund relative to those of other institutions of learning, and to seek their instruction as to the best means of increasing it. It was the most important subject, perhaps, that could be brought to their consideration, but in view of the business immediately before them he deferred enlarging upon it.

The special committee, composed of the Hon. J. B. Henderson, Dr. William L. Wilson, Prof. A. Graham Bell, Dr. J. B. Angell, and the Hon. R. R. Hitt, which had been appointed by the Chancellor in accordance with a resolution passed at the previous meeting to consider the proposal submitted by the Association of Agricultural Colleges and Experiment Stations for the establishment of a Bureau of Graduate Study under the Smithsonian Institution, and all kindred questions, presented a report which dealt comprehensively with the subject (which will be found in the Report of the Regents to Congress), and the committee was discharged.

The Board then adjourned.

APPOINTMENT OF REGENTS.

The Hon. Richard Olney, of Massachusetts, was appointed a Regent to succeed Dr. Johnston, by joint resolution of Congress approved by the President on January 24, 1900, and Dr. Andrew D. White, of New York, was reappointed a Regent by joint resolution of Congress approved June 2, 1900.

As organized at the end of the fiscal year, the Board of Regents consisted of the following members:

The Hon. M. W. Fuller, Chief Justice of the United States, Chancellor; Senator William P. Frye, President pro tempore of the Senate, in place of the Vice-President, deceased; Senator S. M. Cullom; Senator O. H. Platt; Senator William Lindsay; Representative R. R. Hitt; Representative Robert Adams, jr.; Representative Hugh A. Dinsmore; Dr. James B. Angell; Dr. Andrew D. White; the Hon. J. B. Henderson; the Hon. W. L. Wilson; Dr. A. Graham Bell; the Hon. Richard Olney.

ADMINISTRATION.

The conduct of the business of the Institution, the management of the bureaus under its charge, the relations with Congress, with the Executive Departments of the Government, with colleges, universities, societies, and libraries, with foreign establishments, governmental and scientific, and with the thousands of persons who address the Institution seeking aid, counsel and information necessitates details of administrative labors far in excess of what was contemplated in the early days of the Establishment. To these the greater part of the Secretary's time must be given, leaving but a minor portion for engaging in and directing scientific work.

As far as is consistent with an orderly scheme of government, the management of the various interests are left to the officers in direct charge of the several branches of the work. The Secretary feels that he is fortunate in having such efficient and hearty support as he receives from these gentlemen, yet all questions of policy and almost numberless matters of detail arising from Government practice or the regulations of the Regents require his immediate attention and must be passed upon by him or by the Assistant Secretary, who should have more than the merely clerical aid he has at present.

At the annual meeting of the Board of Regents of the Smithsonian Institution, held on January 26, 1898, the following resolution was unanimously adopted:

"*Resolved*, That the Secretary be instructed to request of the President such a modification of the civil-service regulations relating to appointments as will permit an exemption of such scientific positions under the Smithsonian Institution as the Secretary may deem best for the interests of the Institution."

In accordance with this instruction the Secretary formally laid the matter before the President in a communication which, since it has already been the subject of discussion in the public press, may not improperly be here given. It is as follows:

DECEMBER 5, 1898.

The PRESIDENT:

At the annual meeting of the Board of Regents of the Smithsonian Institution, held on January 26, 1898, the following resolution was unanimously adopted:

"*Resolved*, That the Secretary be instructed to request of the President such a modification of the civil-service regulations relating to appointments as will permit an exemption of such scientific positions under the Smithsonian Institution as the Secretary may deem best for the interests of the Institution."

Present: The Chancellor, the Chief Justice of the United States, in the chair; the Vice-President of the United States; Senator Morrill, of Vermont; Senator Cullom, of Illinois; Senator Gray, of Delaware; Representative Hitt, of Illinois; Representative Wheeler, of Alabama; Representative Adams, of Pennsylvania; ex-Senator Henderson, of Washington City; the Hon. William L. Wilson, president of Washington and Lee University; Prof. Alexander Graham Bell, of Washing City; the Secretary of the Smithsonian Institution.

In accordance with this instruction I respectfully request of the President the exemption from the operations of the civil-service regulations of the assistant secretaries in charge of the bureaus of the Smithsonian Institution and of the heads of its several bureaus, namely, the National Museum, the International Exchanges, the Bureau of Ethnology, the Zoological Park, and the Astrophysical Observatory, and to further respectfully represent that the above exemptions are indispensable to enable the Institution to serve the Government's interests as it has hitherto done.

I further respectfully represent that in the opinion of the Regents it is desirable that the Secretary should also have the power, as heretofore, of appointing scientific men of eminence as curators.

I ask to be permitted to state that men of high scientific position have been usually found to be unwilling to subject themselves to examinations, that the Smithsonian Institution has for more than a half century secured to the Government the services of eminent men by selection from the whole body of American science, and that in my opinion the public service will suffer if this can no longer be done.

I have the honor to be, very respectfully, your obedient servant,

S. P. Langley, *Secretary.*

In adopting the recommendations of the Regents the President, on May 29, 1899, amended the civil-service regulations in the following respects:

Under section 3, Rule IV, noncompetitive examinations are permitted to test the fitness of persons whom the Secretary of the Smithsonian Institution shall nominate for appointment in the classified service, provided the Secretary shall certify that in his opinion the positions to be filled "require such peculiar qualifications in respect to knowledge and ability, or such scientific or special attainments wholly or in part professional or technical as are not ordinarily acquired in the executive service of the United States," on which account "an examination should be waived in whole or in part." It is required that the President of the United States shall approve such nominations, whereupon the Civil Service Commission shall grant a certificate of qualification, "upon such evidence as may be satisfactory to it, that the person so nominated is eligible for and may be appointed to such position by reason of his ascertained qualifications and by reason of his age, health, and moral character." Such appointee may not be transferred to any other position in the classified service except to one that may be filled in like manner, "and shall not be assigned to any other duties than those pertaining to the particular position to which thus appointed."

Rule VI is amended to relieve from the requirements of examination or registration the Assistant Secretary of the Smithsonian Institution in charge of the United States National Museum, and "not exceeding one private secretary or confidential clerk to the Secretary of the Smithsonian Institution."

BUILDINGS.

The fitting up of the lower story in the south tower of the Smithsonian building as an exhibition room specifically for children has occupied attention at intervals during the year, and the preliminary work is now approaching completion. To obtain a maximum of light, large doors, fitted with glass, protected where necessary by a light grill of wrought iron, have been placed on the south side, and the windows have been enlarged as far as could be done without interfering with the masonry. The columns which formerly occupied the room have been removed and the apartment finished in light color.

The purpose in establishing this room has not been to appeal to the trained adult mind, but to the untrained and even childish mind, and to group the objects with regard to those characteristics attractive to and comprehensible by the general public, and particularly by children. In this way it is hoped that the child at least will receive impressions which will guide and influence it when serious studies are taken up.

Further progress has been made in the renovation and rearrangement of some of the storage rooms in the south tower, and changes are in progress in the basement of the north tower.

Improvements in the Museum, the Astrophysical Observatory, and the Zoological Park buildings are mentioned elsewhere.

FINANCES.

The permanent funds of the Institution are as follows:

Bequest of Smithson, 1846		$515,169.00
Residuary legacy of Smithson, 1867		26,210.63
Deposits from savings of income, 1867		108,620.37
Bequest of James Hamilton, 1875	$1,000	
Accumulated interest on Hamilton fund, 1895	1,000	
		2,000.00
Bequest of Simeon Habel, 1880		500.00
Deposits from proceeds of sale of bonds, 1881		51,500.00
Gift of Thomas G. Hodgkins, 1891		200,000.00
Portion of residuary legacy of Thomas G. Hodgkins, 1894		8,000.00
Total permanent fund		912,000.00

In addition to the above permanent fund, the Regents hold certain approved railroad bonds, forming part of the fund established by Mr. Hodgkins for investigations of the properties of atmospheric air.

The fundamental act organizing the Institution (Section 5591, U. S. Revised Statutes) was amended by act of Congress approved by the President March 12, 1894, as follows:

> The Secretary of the Treasury is authorized and directed to receive into the Treasury, on the same terms as the original bequest of James Smithson, such sums as the Regents may, from time to time, see fit to deposit, not exceeding with the original bequest the sum of one million dollars: *Provided*, That this shall not operate as a limitation on the power of the Smithsonian Institution to receive money or other property by gift, bequest, or devise, and to hold and dispose of the same in promotion of the purposes thereof.

The permanent fund of $912,000, as above, is deposited, under this provision, in the Treasury of the United States, and bears interest at 6 per cent per annum, the interest alone being used in carrying out the aims of the Institution.

At the beginning of the fiscal year, July 1, 1899, the unexpended balance, as stated in my last report, was $74,703.42. The total receipts for the year were $60,809.81, being $56,400 derived from the interest on the permanent fund in the Treasury and elsewhere, and $4,409.81 received from miscellaneous sources.

The disbursements for the year amounted to $59,294.16, the details of which are given in the report of the executive committee. The balance remaining to the credit of the Secretary on June 30, 1900, for the expenses of the Institution was $76,219.07, which includes the $10,000 specifically referred to in previous reports, as well as the interest accumulated on the Hodgkins and other funds, which is held against certain contingent obligations, besides relatively considerable sums held to meet liabilities which may be expected to mature as a result of various scientific investigations and publications in progress.

Congress charged the Institution during the fiscal year 1900 with the disbursement of the following appropriations:

International Exchanges, Smithsonian Institution	$24,000
American Ethnology, Smithsonian Institution	50,000
United States National Museum:	
Preservation of collections	170,000
Furniture and fixtures	25,000
Heating and lighting	14,000
Postage	500
Repairs to buildings	6,000
Rent of workshops	4,040
Books	2,000
Printing	17,000
National Zoological Park	75,000
Astrophysical Observatory, Smithsonian Institution	10,000

The executive committee has examined all the vouchers for disbursements made during the fiscal year, and a detailed statement of the receipts and expenditures will be found reported to Congress, in accordance with the provisions of the sundry civil acts of October 2, 1888, and August 5, 1892, in a letter addressed to the Speaker of the House of Representatives.

The vouchers for all the expenditures from the Smithsonian fund proper have been likewise examined and their correctness certified to by the executive committee, whose statement will be published, together with the accounts of the funds appropriated by Congress, in that committee's report.

The following estimates for the fiscal year ending June 30, 1901, for carrying on the Government interests under the charge of the Smithsonian Institution were forwarded as usual to the Secretary of the Treasury.

International Exchanges	$24,000
American Ethnology	60,000
National Museum:	
Preservation of collections	180,000
Furniture and fixtures	17,500
Heating and lighting	17,500
Postage	500
Repairs to buildings	21,500
Rent of workshops	4,040
Purchase of specimens	25,000
Books	2,000
Printing	17,000
National Zoological Park	105,000
Astrophysical Observatory	15,000
Observation of Eclipse of May 28, 1900	4,000

The appropriations made by Congress for the fiscal year 1901 were as follows:

International Exchanges	$24,000
American Ethnology	50,000
National Museum:	
Preservation of collections	180,000
Furniture and fixtures	17,500
Heating and lighting	17,500
Postage	500
Repairs to buildings	15,000
Rent of workshops	4,040
Purchase of specimens	10,000
Books	2,000
Printing	17,000
National Zoological Park	75,000
Astrophysical Observatory	12,000
Observation of Eclipse of May 28, 1900	4,000

RESEARCH.

The Institution has continued research work in various fields of science, including experiments in the solution of the problem of mechanical flight, and, through its Astrophysical Observatory, investigations of the solar spectrum. A fuller account of the latter will be found under the proper head.

The Institution has made some experiments during the year on "radio-active substances," based on the discovery by Professor Becquerel in 1896, that uranium salts emit invisible radiations capable of charging electrified bodies and of producing shadow images on sensitive plates.

The Secretary secured from France and Germany specimens of chloride of radium, polonium subnitrate, and other radio-active substances prepared by Monsieur and Madame Curie. These substances were alleged to have the altogether extraordinary property of emitting light, that is, a form of energy, without limit, somewhat like the pretended lamp of the mediæval alchemists. A portion of this which was represented as having never been exposed to the sunlight, and which had certainly been several weeks at least in total darkness, was opened by Dr. Bolton in an entirely dark room, and immediately displayed a feeble light which was, nevertheless, strong enough to enable the photographer to secure a very distinct print of a photograph. Other experiments were made by Dr. Bolton, which will be found fully described in the General Appendix of the Smithsonian Report for 1899.

It is not to be presumed that we have obtained this energy out of nothing, but it remains to be shown what the something is out of which it may have come. This subject has since attracted much interest among chemists in this country as well as abroad. The experiments at the Institution were perhaps the earliest, but not the only ones in this country, and their publication seems to have excited such wide attention as to justify this mention.

THE HODGKINS FUND.

The different branches of research now progressing under grants from the Hodgkins fund are making satisfactory advances.

Prof. William Hallock, of Columbia University, New York, has supplemented his report of last year by a summary of the further progress of his investigation of the motion of an air particle under the influence of articulate speech. The instruments which Professor Hallock has invented, and is now perfecting, have proved a great aid in this research, and will, he states, enable him to settle definitely the question of phase differences in the components of a complex sound.

Prof. A. G. Webster, of Clark University, reports the completion and successful application to the use for which it was designed of the new apparatus, perfected with aid from a Hodgkins grant, by means of which it is now possible to measure the intensity of rapidly varying sounds with an accuracy not hitherto attained. A report of the results of the further experiments of Professor Webster upon the propagation, reflection, and diffraction of sound, the action of the megaphone and the trumpet phonograph, as well as a verification of the theory of resonators, is awaited later.

A grant was approved November 28, 1899, on behalf of Prof. Louis Bevier, of Rutgers College, for an investigation of vowel-timbre on the basis of the phonographic record. This research will endeavor primarily to determine:

1. The characteristic partial tones which differentiate the various timbres recognized by the ear as the vowels of speech.

2. How these partials vary in articulate speech, with stress, pitch of fundamental, etc., and in the transition to other sounds.

This research is still in progress, and will be reported upon more fully, but Doctor Bevier states that the vowels already studied form a series acoustically, quite as truly as phonetically and physiologically.

The meteorological investigations with kites have been successfully continued at Blue Hill under the direction of Mr. Rotch with the assistance of a grant from the Hodgkins fund. During the year ending July 1, 1900, sixteen flights were made in four series in order to obtain the changes with height under different weather conditions, the maximum altitude reached being 14,000 feet on June 21.

In addition to the above investigations a Hodgkins grant has been approved to enable Mr. Rotch to carry on a series of experiments in space telegraphy, it being thought that the unprecedented heights attained by kites might materially extend the range of communication by this method. In the preliminary experiments, however, kites were not used, sufficient elevation being attainable without them, but when the difference between the stations was increased from 1 mile to 3, kites were employed to raise the transmitting and receiving wires. In the later experiments it was found, not unexpectedly, that the long wires, carried up and supported by kites, collected so much electricity as to interfere with and greatly complicate the messages sent from station to station. These interruptions seem to show that the limit of elevation for the receiving wire was under these conditions less than 500 feet. The greatest distance covered in the experiments was approximately 12 miles, from a wire supported by a kite about 200 feet above Blue Hill to the tower of Memorial Hall in Cambridge, which was used as the receiving station. These experiments draw attention to the fact that electrification increases with the altitude to which the wire is carried, and that it is always present, although varying with the meteorological condition of the atmosphere. The experiments were discontinued in the autumn of 1899.

It has been found practicable to approve a second grant on behalf of the journal, Terrestrial Magnetism, which was warmly recommended by the committee for such aid last year, Professor Bauer, the editor, as in the case of the first grant, agreeing to send out a specified number of copies of his journal to scientific men and institutions.

In November of last year an application was received from Dr. Carl Barus, now connected with Brown University, for a grant from the Hodgkins fund in aid of his experiments on atmospheric condensation. This application, having been duly passed upon, was approved.

This research is supplemental to the experiments already conducted by Dr. Barus, as described in Bulletin No. 12, of the Department of Agriculture, and will be:

1. A study of the origin, activity, and growth of the condensation producing dust particles; their reactions on each other, their relation to electric radiation, etc.

2. A study of the growth, etc., of water corpuscles after condensation; the reaction of corpuscles of different sizes on each other, etc.

A preliminary report was submitted by Dr. Barus, and, in accordance with the usage of the Institution and as a matter of interest to those engaged in similar researches, he has been invited to publish in the scientific journals a detailed account of his experiments.

A grant has been approved on behalf of Prof. Dr. R. von Lendenfeld, of the University of Prague, for a study of the motion of birds in actual free flight, a subject to which, although primarily known as a zoologist and meteorologist, Dr. von Lendenfeld's attention has been directed for years, and for the better understanding of which he has made numerous anatomical preparations, physiological observations, etc. The investigations of Dr. von Lendenfeld have been aided by the Society for the Advancement of Scientific Research in Bohemia, and also by the Austrian Government. His publications have been numerous, the simultaneous issue in German and English of his monograph on flight having been arranged for by the author with Mr. Fischer in Jena and Messrs. Macmillan & Co. in London.

Dr. von Lendenfeld's published work on his Australian explorations and researches was submitted to the Institution in 1893, at which time he entered his application for a grant, since fully considered and advised upon, and now approved as above stated.

Since my last report an application has been received for a grant in aid of the researches on the spectrum which have been prosecuted with ardor by Dr. V. Schumann, of Leipsic, for several years. As is the custom, the question of the advantage to science of such a grant was referred to leading specialists, both in this country and Europe. The testimony thus obtained as to the value of the work already accomplished by Dr. Schumann, added to my own knowledge of his investigations, led to the approval of a subvention from the Hodgkins fund for the prosecution of researches in connection with the spectral relations of atmospheric air. The apparatus by means of which Dr. Schumann has heretofore secured such noteworthy results being chiefly of his own invention, he has been permitted to apply the present grant to the further perfection of his instruments before entering upon his special experiments, which will be definitely reported upon as they progress.

As referred to in my last report, in accordance with the purpose of the Institution, copies of the Hodgkins prize memoir, *La Vie sur les hauts Plateaux*, which were obtained through the authors, Drs. Herrera and Lope, have been distributed to the libraries and educational institutions of the country, thus making a valuable work accessible in widely separated localities.

In October of last year copies of the Hodgkins medal in silver and bronze were presented to Pembroke College, Oxford, England, of which establishment James Smithson, the founder of the Institution, was a graduate. The receipt of the medals was acknowledged in the following letter from the Right Rev. Lord Bishop Mitchison, master of Pembroke College, through whom the presentation was made:

PEMBROKE COLLEGE, OXFORD, *November 19, 1899.*

DEAR DR. LANGLEY: Yesterday your kind present of the copies of the Hodgkins medal of the Smithsonian Institution came safely to hand, and on behalf of myself and of the college I tender you my best thanks for a beautiful and interesting gift. The medals will form a suitable adjunct to the cases of books from the Institution, which form, as you know, a feature in our college library.

Believe me to be, very faithfully, yours,

J. MITCHISON.

In order that the scope permitted by the will of the donor in expending the income from the Hodgkins fund may not fail to be understood by those likely to be interested in the range of researches which may be thus fostered, a circular, a transcript of which follows, has been recently issued:

SMITHSONIAN INSTITUTION.

[Presiding officer ex officio, the President of the United States; Chancellor, the Chief Justice of the United States.]

THE HODGKINS FUND.

In October, 1891, Thomas George Hodgkins, Esq., of Setauket, New York, made a donation to the Smithsonian Institution, the income from a part of which was to be devoted "to the increase and diffusion of more exact knowledge in regard to the nature and properties of atmospheric air in connection with the welfare of man."

These properties may be considered in their bearing upon any or all of the sciences—*e. g.*, not only in regard to meteorology, but in connection with hygiene, or with physics, or with any department whatever, either of biological or physical knowledge.

With the intent of furthering the donor's known wishes, the Institution has already given considerable money prizes for treatises embodying new and important discoveries in regard to the nature or properties of air. This form of encouragement will not at present be renewed.

A gold medal has been established under the name of the "Hodgkins Medal of the Smithsonian Institution," which will be awarded annually or biennially for important contributions to our knowledge of the nature and properties of atmospheric air, or for practical applications of our existing knowledge of them to the welfare of mankind, and grants of money are made from time to time to specialists engaged in original investigations which involve the study of the properties of atmospheric air.

These properties may be understood in the widest sense of the word. Thus the physicist may consider them in an investigation which involves the study, for instance, of atmospheric electricity, or of the absorptive powers of the air, or of the atmospheric lines in the spectrum; the hygienist may be assisted in researches in this connection looking to the promotion of health; or even the geologist, in a study which connects the earth's crust with the absorption of the constituents of the atmosphere in past or coming time. Thus the Hodgkins Fund may be considered to cover in effect something belonging to nearly every division of the applied sciences.

It being the desire of the Institution to give the widest extension to the great purpose of the founder of this fund, and to prevent any misapprehension of his wishes, it is repeated, then, that the discoveries or applications proper to be brought to the consideration of the Institution may be in the field of any department of science without restriction, provided only that they have to do with "the nature and properties of atmospheric air in connection with the welfare of man."

The following conditions are imposed with a view to obtaining the fullest possible benefit to science from grants made from the fund:

1. Applications for grants should have the endorsement of some recognized academy of sciences, or other institution of learning, and should be accompanied by evidences of the capacity of the applicant, in the form of at least one memoir already published by him, based upon original investigation.

2. The purchase of necessary laboratory appliances for the particular research in view is authorized, and in special cases on explanation by the applicant, the payment of the salaries of assistants in prosecuting such research; but the defrayment of the purely personal expenses of the grantee is not intended to be provided from moneys advanced from the Fund.

3. Upon the conclusion of a research, it is expected that any special piece or pieces of apparatus purchased from a grant from the Fund will be returned to the Smithsonian Institution.

4. Should investigations for which a grant has been made be of considerable duration, a summary of progress should be submitted to the Institution at the end of six months, as well as a subsequent report in which the results of such investigations may be recorded.

5. The Institution does not claim any legal property in a research promoted by its aid, but it expects to make the first publication of the results obtained, if it desire to do so. If this can not be done without delay, and if the results seem to require it, the Institution has, when

requested, hitherto opposed no obstacle to the publication elsewhere of the fullest abstract of such results, with the understanding that acknowledgment shall be made in any such preliminary publication of the assistance given by it in promoting the research in which the advances have been made.

All communications in regard to the Hodgkins Fund, medals and publications, and all applications for grants of money, should be addressed to

S. P. LANGLEY,
Secretary of the Smithsonian Institution,
Washington, U. S. A.

NAPLES TABLE.

In accordance with the urgent desire of many of the leading biologists of the country, a contract for the Table in the Naples Zoological Station for a third term of three years was entered into in February, 1900, and appointments to the seat were at once approved.

Dr. B. M. Duggar, of Cornell University, was accorded the seat for six weeks during February and March, 1900.

Asst. Surg. V. G. Heiser, of the United States Marine-Hospital Service, was permitted to use the Table at periods suited to his convenience while stationed at Naples during the months of March and April, 1900. As in this instance, the kindness of Dr. Dohrn, the Director, renders a double occupation frequently possible, thus adding materially to the service of the Table.

It is a matter of regret that Mr. Willard G. Van Name, who received the appointment for six weeks during the spring, was prevented by illness from filling his term at the Table.

Dr. T. H. Morgan, of Bryn Mawr College, who occupied the Smithsonian seat six months during the winter and spring of 1894–95, and has since served temporarily on the Smithsonian Advisory Committee for the Table, was reappointed for a part of June and July, 1900.

The application of Dr. P. C. Mensch, of Ursinus College, Pennsylvania, was approved for the month of November, 1900.

Dr. E. B. Wilson, Columbia University, New York, has returned to this country and resumed his duties as a member of the Advisory Committee. Each succeeding year renews the Secretary's sense of obligation to the committee for the assistance afforded him in recommending action on the various applications for the Smithsonian seat.

The reports of the different investigators appointed to the Table show that the advantages for research enjoyed at Naples are appreciated by them; they also testify to the earnest desire of the Director and his assistants to render all possible aid to those conducting researches at Naples.

It may be noted that the established condition requiring an applicant for the Table to submit, with his request for the seat, a summary of his scientific history, including a list of his published works, is not only an aid to the Institution in passing upon the question of appointment, but tends directly to the personal advantage of the student at Naples, as a summary of such history is forwarded to Dr. Dohrn with each notice of appointment.

EXPLORATIONS.

While it has never been possible for the Institution to devote large amounts from its income for carrying on explorations, it has nevertheless been able to promote such work in various ways, particularly in connection with the bureaus of the Institution and in cooperation with the Executive Departments of the Government. The explorations have in these directions had a very wide range, and have been productive of a very great increase in the knowledge of the natural history of the regions visited and of the ethnological conditions of the people.

During the past year the Institution has thus been more or less directly concerned in explorations in various parts of the world, from the arctic regions as far south as Patagonia, and in the distant possessions in the Philippines, as well as in South Africa.

In the pages devoted to the National Museum, the Bureau of Ethnology, and the Zoological Park the detailed results of explorations are narrated and need not be repeated here.

PUBLICATIONS.

Through the publications of the Institution and its bureaus, much is done each year in carrying out one of its fundamental objects, the "diffusion of knowledge." Works covering practically every branch of human knowledge have been distributed throughout the world to libraries and institutions where they may best be available to scholars and to the reading public.

The Institution itself publishes three established series—the Contributions to Knowledge, the Miscellaneous Collections, and the Annual Reports. In the first series, in quarto form, are published original researches in various branches of science. The series of Miscellaneous Collections, in the words of Secretary Henry (Smithsonian Report, 1861), "includes works intended to facilitate the study of the various branches of natural history, to give instruction as to the method of observing natural phenomena, and a variety of other matter connected with the progress of science. Although the object of the Institution is not educational, yet in carrying out the general plan it has been thought important in some cases to publish elementary treatises, which will not only furnish an introduction to special subjects to those who have not access to expensive libraries, but also serve to point out the way in which individuals by special studies can not only promote their own enjoyment, but also cooperate with all others engaged in the same pursuit in extending the domain of knowledge. The objects of nature, like the specimens of high art, are the luxuries of the cultivated mind, and the awakening of a taste for the study affords an inexhaustible source of pleasure and contentment to the most numerous and the most important classes of the community."

In carrying out the policy planned for the Miscellaneous Collections, there have been published in the 40 volumes of that series 106 bio logical papers, 67 physical papers, and 22 papers of a business character, such as lists of libraries, publications, and of correspondents.

The Annual Reports are accompanied by an appendix distinct in purpose from the other publications of the Institution. Formerly the Institution published a summary of the progress of science in all its branches during the year, but this grew so increasingly inadequate with the more numerous fields that science occupied that it was discontinued, and in its place has been published a series of articles, occasionally original, but more frequently drawn from other and nontechnical publications, giving short popular memoirs by writers of authority on the subjects familiar to each, and collectively a résumé of those of most special interest in all departments of science which have appeared during the year. The special characteristic of these memoirs is that, while authoritative, they are nontechnical and of interest to the general reader, and there are few portions of the work of the Institution which more effectively serve in the diffusion of knowledge than this.

The Institution publishes through the National Museum the Proceedings and the Bulletin and an Annual Report. Through the Bureau of Ethnology there are likewise issued very complete works on American Ethnology.

During the past year the Annals of the Astrophysical Observatory have for the first time appeared, the first volume having been put to press and practically published at the close of the fiscal year. This work is discussed somewhat in detail in the paragraph devoted to the Observatory. It is an exhaustive account of the work of the Secretary during a long series of years in his study of the infra-red solar spectrum, a work begun at Allegheny in 1878, and continued in the Astrophysical Observatory of the Smithsonian Institution.

An important work put in type during the year, under special authority of Congress, was a Documentary and Legislative History of the Institution from 1836 to 1899, comprising about 1,900 pages, to be published in two volumes.

There has also been in hand a second Supplement to Bolton's Bibliography of Chemistry, giving about 6,000 titles of academic dissertations. The first part of the Museum portion of the Smithsonian Report for 1897 was distributed early in the year; but the second part, to consist of some of the more important papers by the late Assistant Secretary, Dr. Goode, has not been completed. Both the Smithsonian and Museum volumes of the 1898 Report were put in type, but it was impossible to issue them in bound form before the year closed.

In order to meet the demand for information in regard to the aboriginal antiquities of the West Indies, the Institution reprinted from the Reports for 1876 and 1884, descriptions of the Latimer Collection from Porto Rico and of the Guesde Collection in Pointe-a-Pitre, Guadaloupe.

Of the Proceedings of the National Museum, Volume XXI was published in bound form, and 23 papers included in Volume XXII were issued as pamphlets.

As the principal paper in the Museum Report for 1898, it seemed advisable to publish an exhaustive monographic treatise by the late Professor Cope on the Crocodilians, Lizards, and Snakes of North America.

The elaborate work by Drs. Jordan and Evermann on the Fishes of North and Middle America was brought to completion by the publication of Part 4 of Bulletin 47 of the Museum, this part consisting of 392 plates, with explanations, and a general table of contents of the four parts of the work.

The Bureau of American Ethnology issued Part 2 of the Seventeenth Annual Report, but Part 1 has been delayed. The Eighteenth and Nineteenth Reports are also in the hands of the Government Printer, and some progress has been made in the printing of the first bulletin of a new series authorized by Congress.

LIBRARY.

The number of volumes, parts of volumes, pamphlets, and charts added to the library has aggregated 25,701. As this appears to show a decrease over previous years, it seems well to record the fact that the decrease is apparent and not real. From the inception of the Institution each item, even a periodical issued weekly, was separately entered in the accession book. Last year the number of such items aggregated over 36,000, and the clerical labor involved was very great. Inasmuch as the separate parts were checked upon cards, it seemed advisable to give up the old system which, while affording an absolutely permanent record of each item, involved an expenditure of energy disproportionate to the result. The Librarian of Congress and the librarian of the Institution joined in recommending this change.

From January 1, 1900, only completed volumes were entered in the accession book.

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

The third and final conference on an International Catalogue of Scientific Literature was held in London June 12 and 13, 1900, and the United States Government was invited to participate, through the

Department of State, as it has in the previous conferences. The invitation requested the appointment of delegates prepared to pledge their governments to definite support of the undertaking; and to meet this condition the Secretary of State urged upon Congress an appropriation of $10,000 for the purpose. As Congress adjourned without making the grant, it appeared that no authority existed to send a representative to the conference with the powers stipulated in the terms of the invitation, and accordingly none was sent. This result is greatly to be deplored, since probably no country has a larger interest in scientific bibliography than the United States.

So keenly was the absence of American co-operation felt, and the danger of the entire failure of the undertaking was so apparent should American aid not be forthcoming, that the Secretary informally agreed to draw upon the slender resources of the Institution temporarily, and furnish to this international undertaking an index of American scientific literature.

It is hoped that in some way Congress may be brought to see the importance of this undertaking, and make adequate provision. It would constitute a real reproach to the country, should America not do its share in this work.

GALLERY OF ART.

The act of foundation of the Institution declares (section 5586 of the Revised Statutes) that "whenever suitable arrangements can be made from time to time for their reception, all objects of art and of foreign and curious research, all objects of natural history, plants, and geological and mineralogical specimens belonging to the United States * * * shall be delivered to such persons as may be authorized by the Board of Regents to receive them, and shall be so arranged and classified in the building erected for the Institution as best to facilitate the examination and study of them;" so that the first object of the Institution, in the eyes of its founders, appears to have been to give it the curatorship of the ART collections of the nation.

During its early years this object was promoted in various ways; among others by the purchase of a very valuable collection of prints and engravings belonging to the Hon. George P. Marsh. After the fire in the Institution in 1865 these prints were deposited for temporary safe keeping in the Library of Congress and (with other works of art) in the Corcoran Gallery.

Subsequently an appropriation was granted by Congress for making a fireproof room in which these could be kept, but it was not until 1896 that the Regents provided for their recall to the Institution. In the journal of the proceedings of the Board for 1896 (Smithsonian Report, 1896, pp. xiii and xiv) will be found the action taken by the Board providing for their restoration to their own immediate control. The following resolution offered then by Senator Gray was adopted:

> *Resolved*, That the question of the propriety of bringing the works of art belonging to the Institution under the more immediate control of the Board of Regents be referred to the Executive Committee and the Secretary, with power to act.

In pursuance of this the Institution brought back to its own keeping a number of prints of value, both from the Library of Congress and the Corcoran Gallery, leaving, by an amicable understanding with the latter establishment, as a loan, a few of the works of art, notably a large picture by Healy.

The old name of the collections was the "Gallery of Art," a title which seems almost too ambitious for the present collections of the Institution, though it is to be hoped that this designation will be justified by their future increase. These have been placed by me in a room specially fitted up for that purpose (the Art Room), under the temporary charge of the librarian.

THE CHILDREN'S ROOM.

An educational museum has been elsewhere defined as "a collection of instructive labels, each illustrated by a well-selected specimen;" but though the first purpose of a museum be for the increase of original knowledge by investigation and research, its second purpose is to entertain as well as to instruct. To some extent the scientific system of classification which requires a Latin name on every natural-history specimen is associated with a treatment on the label which does not principally consider what interests, but what instructs, and makes the collection less entertaining than it might otherwise be to the general public; but this, the customary arrangement, while right and necessary for scientific purposes, and the one which must always chiefly prevail, is not that which is most readily "understanded of the people," almost the only way to whose comprehension lies through a newly awakened interest and attention. It may truthfully be said that not one in twenty persons who enter a museum of natural history does profit in this sense by the intelligence conveyed along with the Latin name, and though our own labels are chiefly in English, and though the wants of this public have already been considered in the National Museum in the collections as now displayed, it might seem to be possible to do yet a little more and to place at least in a restricted space specimens which will engage the interest of the majority of the public and especially to bring these things within the reach of children.

Speaking for myself, and I believe for most other students of science, I may say that each will usually recognize that his "bent" toward his particular study came to him at a very early period of his life, when something which excited his childish wonder grew to have unaccountable attraction, which developed into a lifelong pursuit. At least if he can remember, he will find that this "bent" did not begin in a dry instruction, but in something which powerfully interested him.

This has been recognized as true philosophy from the time when Aristotle said "Knowledge begins in wonder;" and with it in view I have felt desirous of devoting at least some small portion of the collections to the purpose of stimulating the wonder and interest of all the unlearned, and especially of the children, and I am fitting up in the south tower of the Smithsonian building a small room on the ground floor which is to be called the "Children's Room." The little group of specimens it contains is meant to stimulate, interest, and entertain rather than to ostensibly instruct. Latin is banished from its labels, and the classification is not that of science, but that which is most intelligible to the untrained mind.

I shall return to this subject in a future report, when I can speak both of the completion of the collection, which is not yet finished, and, I hope, of useful results in the direction for which it is intended.

CORRESPONDENCE.

The correspondence of the Institution embraces letters having reference not only to the scope of work of the Institution, but also relating to the bureaus placed by Congress under its direction. Many letters relating exclusively to the activities of the bureaus mentioned are referred to them for attention and answer, but those involving in any way the policy of the Institution or relating to other than routine matters are referred to the Secretary.

As in former years, a considerable amount of correspondence relates to matters not strictly within the purview of the Institution's interests, but it has been the endeavor in every instance where the information desired could be readily obtained to supply the wants of the applicant. Where the inquiry addressed to the Institution appears to come within the immediate scope of the functions of some other branch of the Government service, the communication has been referred to the chief of the department or bureau concerned, and the writer so informed. The correspondence of the Institution is perhaps more varied and embraces a wider range of subjects than obtains in other departments of the Government, and but a very small percentage of the letters received, concern business of a routine nature. It can readily be understood that this circumstance requires an unusual amount of energy and labor on the part of the staffs of the Institution and its several bureaus to properly reply as fully as possible to correspondents.

The system inaugurated in 1890, of registering and referring letters received at the Institution, when of sufficient importance to warrant a permanent record of them, has continued in successful operation, and entries have been promptly made and any arrears avoided.

COOPERATION OF EXECUTIVE DEPARTMENTS.

The several Departments of the Government have always generously cooperated in furthering the interests of the Institution, particularly in collecting objects of biological or ethnological interest, and the results of such cooperation are particularly seen in every department of the Museum. Among those who have been most active in increasing the collections have been officers of the Army and Navy who have voluntarily given their services to the work.

In order to promote and increase the interest in the Institution on the part of the officers of the United States resident in foreign countries, the Secretary of the Institution issued circulars to be sent to United States consuls and to army and navy officers. The forms of these circulars were printed in the last Report, and it is gratifying to note that a considerable number of objects have already been thus acquired, as mentioned elsewhere.

EXPOSITIONS.

By act of Congress approved March 3, 1899, the sum of $300,000 was appropriated for a Government exhibit at the proposed Pan-American Exposition to be held at Buffalo in 1901.

The Government Board of Management in charge of the preparation of the exhibit having apportioned a part of the sum for a display by the Smithsonian Institution and its bureaus, considerable progress has been made during the year in gathering objects that would best illustrate the work of the Institution. In this connection a few objects connected with the history of art will be exhibited on the part of the Institution, but the collection will chiefly consist of specimens illustrative of its scientific functions, and more especially in the National Museum and Bureau of Ethnology. An opportunity was thus afforded for gathering biological collections in Cuba, as well as objects chiefly of ethnological interest from the Philippines.

INTERNATIONAL CONGRESS OF ORIENTALISTS.

As mentioned in the last report, the Secretary, on December 9, 1898, designated Dr. Paul Haupt, of Johns Hopkins University, as delegate of the Institution to the Twelfth International Congress of Orientalists at Rome, on October 3–15, 1899; and Dr. Haupt, as well as Prof. Charles R. Lanman, of Harvard University, and Prof. Morris Jastrow, of the University of Pennsylvania, were, upon recommendation of the Secretary, appointed as delegates of the United States Government.

The congress was a notable one, nearly 600 persons being present, of whom 15 were from the United States, and a number of valuable papers were presented by the American members. One important outgrowth of the meeting was the establishment of an International Association for the archæologic exploration of India. The next congress will be held in December, 1902, in Hamburg, Germany, while Athens has been proposed as the place of meeting for the Fourteenth Congress.

STANDARDS OF COLOR.

Mr. Robert Ridgway, curator of ornithology in the National Museum, published a number of years ago, for the use of naturalists, a handbook on color, and he requested a grant from the Institution for a new edition. It appeared to the Secretary that a work upon a more extended scale and a somewhat different plan would be of value primarily to naturalists, but also in every department of science, to artists, and in many branches of industry.

At the present time there is practically no uniformity in the common use of color names, one name designating as a rule as many as half a dozen different shades; nor is there any absolute method commonly available by which a person in one place can describe to a person in another the exact shade or tint meant by a given name. The production of a work which would obviate these difficulties and make available what might be called the "CONSTANTS OF NATURE" in color, is directly in line with previous publications of the Institution in endeavoring to establish standards whereby a definite nomenclature in scientific and popular writing might be introduced.

The conception is that of a comprehensive and important work, and this has been under consideration for some time, for it has been felt that it could not be undertaken by the Institution unless it was to be done in a worthy manner. One of the difficulties in such books as they have hitherto been published, is that they are absolutely dependent upon color illustrations which fade with time, so that the original tints, which should be the standards of comparison, can not be recovered.

The Secretary, after consulting with others expert in the matter, decided that it would be desirable not only to secure more permanent tints, but to connect every tint published in the book with some definite wave length in the spectrum, whether the solar spectrum or a composite one. The investigations of Professor Rood and others show that it is difficult to do this directly, but that it can be effected by the use of intermediate means of comparison.

Again, experiments must be made to determine how far this large object (of connecting every tint employed with some definite wave length or combination of wave lengths of light) is practicable. If it be fully so, the work may be said to be in one sense something absolutely permanent, relating as it will to standards which can never alter with time, so that, as has been said, those who expect that their writings will be more permanent than the planet itself should take this method of illustrating them.

The work promised such magnitude that a committee was appointed, as follows: Mr. Ridgway, curator of the ornithology in the National Museum, as possible editor; Mr. Holmes, head curator of anthropology, and known as an artist of ability; Dr. Gill, the distinguished naturalist, and Dr. Adler, the librarian of the Institution, who has been charged to procure information on the history of the subject. To these it is quite probable there will be later added a physicist and possibly a special colorist, unless these last two qualifications can be found combined in the same person, which is hardly probable.

NATIONAL STANDARDIZING BUREAU.

The Hon. James H. Southard, chairman of the Committee on Coinage, Weights and Measures of the House of Representatives, invited the Secretary to appear before the committee last April in regard to the merits of a bill then before Congress for the establishment of a bureau of standards, but he was unfortunately prevented from doing so by other engagements.

It is proper to say, however, that the establishment of a bureau of standards is a matter in which the Secretary has been always greatly interested, and that at the request of the Superintendent of the Coast Survey he had an interview with him and made some suggestions in reference to proposed legislation.

The Secretary was the first to establish a practical plan, which was afterward very generally adopted by the railways of the United States, for communicating standard time over long distances, and he has always taken a special interest in the subject of determinations of exact measurements in other ways.

The Smithsonian Institution has preserved in its Museum sets of standards of the United States, and the Secretary has also personally commenced a collection of instruments to illustrate the history of standards in all countries. Certain archaic specimens which have been acquired for this purpose are being at the present time arranged.

He takes this opportunity of recording the fact of his interest in the measure now before Congress for the establishment of a national bureau of standards, and saying that his testimony, if given before the Committee on Coinage, Weights and Measures, would have been in favor of the plan proposed in the bill under consideration.

PROPOSED CHALCEDONY PARK.

The region known as the Petrified Forest in Arizona has been a place of much popular and scientific interest, and at various times the question of setting the region apart as a Government reservation has been agitated but without any definite action until the past year, when, as a result of correspondence between the Institution and the General Land Office, the further removal of fossil trees has been prohibited.

Prof. Lester F. Ward visited the region in November, 1899, and the results of his examination have been published by the Department of the Interior.

The Secretary of the Smithsonian Institution received the following letter from the honorable Commissioner of the General Land Office:

PETRIFIED FOREST, ARIZONA.

DEPARTMENT OF THE INTERIOR,
GENERAL LAND OFFICE,
Washington, D. C., June 17, 1899.

SIR: I am in receipt of a certified copy of a memorial by the legislature of Arizona praying that certain lands in Apache County, Ariz., in the vicinity of the town of Holbrook, known as the "Petrified Forest," be withdrawn from entry with a view to creating a reservation or national park for the purpose of preserving the natural wonders and curiosities of the same.

I have the honor to request that you will kindly inform me whether the records of the Smithsonian Institution furnish any information respecting this locality indicating that the scenic features of the same are of such a nature as to render it desirable, in the interest of the public, to set these lands apart as a national park. I will be pleased to receive a full expression of your views on this subject, and also as to the importance of preserving the mineralized formations in that region.

Very respectfully, BINGER HERMANN,
Commissioner.

The SECRETARY OF THE SMITHSONIAN INSTITUTION.

To this letter the following reply was made:

SMITHSONIAN INSTITUTION,
Washington, D. C., July 7, 1899.

SIR: I have the honor to acknowledge the receipt of your communication of the 17th ultimo requesting information concerning the Petrified Forest near Holbrook, in Arizona, as well as an expression of opinion concerning the desirability of setting aside these lands as a national park, and beg to furnish the following statement:

The region near Holbrook, Apache County, Arizona, known as the "Petrified Forest," "Chalcedony Park," and "Lithodendron (stone trees) Valley," is of great interest because of the abundance of its beautiful petrified coniferous trees, as well as of its scenic features. The trees lie scattered about in great profusion, but none stand erect in their original place of growth as do many in the Yellowstone National Park. The National Museum possesses three splendid trunks collected there by Lieutenant Hegewald at the request of General Sherman.

The best popular account of this region is given by Mr. George F. Kunz, and is as follows:

"Among the great American wonders is the silicified forest, known as Chalcedony Park, situated about 8 miles south of Carrizo, a station on the Atlantic and Pacific Railroad, in Apache County, Arizona. * * * The locality was noticed in 1853 by the Pacific Railroad Exploring Survey. * * * There is every evidence to show that the trees grew beside some inland sea. After falling they became water-logged, and during decomposition the cell structure of the wood was entirely replaced by silica from sandstone in the walls surrounding this great inland sea.

"Over the entire area trees lie scattered in all conceivable positions and in fragments of all sizes, the broken sections sometimes resembling a pile of cart wheels. * * * A phenomenon perhaps unparalleled and the most remarkable feature of the park is a natural bridge formed by a tree of agatized wood spanning a canyon 45 feet in width. In addition to the span, fully 50 feet of the tree rests on one side, making it visible for a length over 100 feet."

Lieutenant Hegewald writes:

"I rode down the valley to examine the thousands of specimens that lay scattered on each side of the valley along the slopes, which were perhaps 50 feet high; the valley of the Lithodendron, at its widest part, being scarcely a half mile. Along the slopes no vegetation whatever was to be seen, wood being very scarce; the soil was composed of clay and sand mostly, and these petrifactions, broken into millions of pieces, lay scattered all adown these slopes. Some of the large fossil trees were well preserved, though the action of heat and cold had broken most of them in sections from 2 to 20 feet long, and some of these must have been immense trees; measuring the exposed parts of several, they varied from 150 to 200 feet in length, and from 2 to 4½ feet in diameter, the centers often containing most beautiful quartz crystals."

Dr. Walter Hough, of the Smithsonian Institution, who has visited the park, writes as follows:

"In the celebrated Petrified Forest, which is some 18 miles from Holbrook, Arizona, on the picturesque Santa Fe Railroad, there are ruins of several ancient Indian villages. These villages are small, in some cases having merely a few houses, but what gives them a peculiar interest is that they were built of logs of beautiful fossil wood. * * * The prehistoric dwellers of the land selected cylinders of uniform size, which were seemingly determined by the carrying strength of a man. It is probable that prehistoric builders never chose more beautiful stones for the construction of their habitations than the trunks of the trees which flourished ages before man appeared on the earth.

"This wood agate also furnished material for stone hammers, arrowheads, and knives, which are often found in ruins hundreds of miles from the forest."

This "wood agate" or "wood opal" is now cut and polished into floor tiling, mantels, clock cases, table tops, paper weights, etc. The silver testimonial to the French sculptor Bartholdi, made by Tiffany & Co., had for its base a section of this wood agate.

Prof. Lester F. Ward, an eminent paleobotanist, who, while officially attached to the staff of the United States Geological Survey, also holds the position of associate curator in the National Museum, expects to visit the Pacific coast this summer, and may return by the southern route. He tells me that if you so desire he would be pleased to visit the region in question for the special purpose of procuring further information regarding the features covered by your inquiry.

In conclusion I would say that all with whom I have consulted are agreed that the "Petrified Forest," or "Chalcedony Park," of Apache County, Arizona, should be preserved as a public park for the benefit of the American people. In no other area is there such a profusion of highly colored stone trees. Fossil wood is scattered over a very great area of Arizona, but the densest portion and chief place of interest is "Chalcedony Park," an area of less than 5 miles square. This region is about 20 miles south of Carrizo station.

A list of papers relating to the Arizona forest trees is appended.

Very respectfully,

Richard Rathbun,
Acting Secretary.

Hon. Binger Hermann,
Commissioner General Land Office,
Department of the Interior, Washington, D. C

MISCELLANEOUS.

Gifts.—Among the gifts to the Institution during the year may be mentioned an extensive and valuable collection of archæological objects presented to the Institution by Mr. Joseph D. McGuire, of Washington.

Smithson tablet.—The bronze tablet affixed, by the direction of the Regents, to the tomb of Smithson in Genoa, having been stolen, it has been ordered to be replaced by one in Carrara marble.

Foreign institutions.—Dr. Andrew D. White, ambassador to Germany and a Regent of the Institution, was designated to represent the latter at the celebration of the two hundredth anniversary of the Royal Prussian Academy of Sciences, at Berlin, on March 19 and 20, 1900.

Dr. White attended, and, in his report of the ceremonies, suggested that the formal congratulations of the Institution should be suitably engrossed and forwarded to the Royal Academy. This was done through the Department of State.

The congratulations of the Institution were also sent to the Kaiserlich-Königliche Geologische Reichsanstalt, on the occasion of its fiftieth anniversary, and to the Königlich Sachsischen Altertumsverein on the occasion of its seventy-fifth anniversary.

THE NATIONAL MUSEUM.

Of the several bureaus of the Smithsonian Institution the National Museum is of most general interest, and the administration of its business has demanded most care.

The primary object of the Museum is the acquisition, preservation, and classification of the collections of the Institution and the Government, which relate to nearly every branch of human knowledge. The placing of these, when arranged by their curators, on public exhibition in such a manner as best to afford to visitors an opportunity to acquire accurate general information concerning them may be regarded as a necessary adjunct, and serves not only as a means of instruction but also as a source of entertainment to the public.

The foundation of the Museum collections was the number of ethno logical and biological objects brought to the United States more than half a century ago by the Wilkes Exploring Expedition, and the collections made by explorers for the Smithsonian Institution, to whose care these materials and every other object of natural history were later transferred.[1] The preservation and classification of these objects was the work of those who for a number of years had charge of the Government collections in the United States Patent Office, and when these were transferred to the custody of the Smithsonian Institution and were placed on exhibition, and as other large collections were added to the Museum, there came gradually into existence a store of valuable objects, which were, however, unconsecutive and not only often duplicated, but frequently unrelated owing to the mode of their acquisition.

At the close of the Centennial Exhibition of 1876 at Philadelphia a great number of collections, chiefly of industrial interest, became the property of the Smithsonian Museum. For the accommodation of these objects, a one-story building was begun in 1879 and completed in 1881, containing an area of about 80,000 square feet, and built in the cheapest manner. This structure was so entirely inadequate to the object for which a building of five or six stories over the same area would have barely sufficed, that within two years from its completion it was found to be too limited for the display of the exhibits then actually on hand.

It was proposed as early as 1882 to provide additional quarters for the Museum, with the object of giving accommodation also to the Geological Survey, there being a proviso in the bill, however, that the pro-

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[1] "Whenever suitable arrangements can be made from time to time for their reception, all objects of art and of foreign and curious research, and all objects of natural history, plants, and geological and mineralogical specimens belonging to the United States, which may be in the city of Washington, in whosesoever custody they may be, shall be delivered to such persons as may be authorized by the Board of Regents to receive them, and shall be so arranged and classified in the building erected for the Institution as best to facilitate the examination and study of them; and whenever new specimens in natural history, geology, or mineralogy are obtained for the Museum of the Institution, by exchanges of duplicate specimens, which the Regents may in their discretion make, or by donation, which they may receive, or otherwise, the Regents shall cause such new specimens to be appropriately classed and arranged." (Sec. 5586, U. S. Revised Statutes.)

posed building should always remain under the absolute direction of the Regents.[1]

The Secretary, in his report for 1888, represented to the Regents the insufficiency of the existing accommodations for the collections already in the possession of the Museum, which at that time, within seven years after the completion of the present Museum building, was already found to be wholly inadequate. The history of the Museum since then has been a uniform one of representations to Congress by the Regents of the increasing insufficiency of its building and lately its intolerable inadequacy.[2]

In 1899 the Secretary took occasion to say to the Regents:

"The nation has given an adequate house to its great collection of books. Has not the time come to finally ask of Congress the provision of an adequate home for this greater collection of specimens, a project which was dear to the heart of your late colleague, Senator Morrill, and one which he urged with almost his last breath?"

It has already been observed that by far the greater portion of the treasures of the Museum have been acquired by Government explora-

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[1] The proposition was not viewed favorably by the Board, the Chancellor stating "that it was desirable that new Museum buildings should be erected in any case, but that since by an act of Congress a certain part of the public grounds had been set apart and appropriated absolutely and exclusively to the Smithsonian Institution, he for one did not want to see anything else placed on these grounds."

He further said: "If the Smithsonian Institution is to grow, it will need them all, and whatever is put upon them should be under our exclusive control." (Journal Proceedings of Regents, page xv, Report 1888.)

The remarks of the Regents in discussing this proposition indicated clearly that the view of the Chancellor had their unanimous approval.

[2] A bill was introduced by Senator Morrill on June 12, 1888, for the erection of an additional Museum building, and the measure was favorably acted upon by the Senate, but failed in the House. On June 21 of the same year Senator Morrill moved the provisions of the bill in the form of an amendment to the sundry civil bill for 1889, and at the following session (January 17, 1889) he again introduced this provision as an amendment to the sundry civil bill for 1890.

In the Fifty-first Congress Senator Morrill again reported, from the Committee on Public Buildings and Grounds, the bill for a new Museum building, which bill was passed by the Senate April 5, 1890, and not being reported in the House, was, on June 24, 1890, as in previous sessions, again reported by Senator Morrill as an amendment to the sundry civil bill (for 1891), which amendment was agreed to by the Senate, but failed in conference, as before. On January 9, 1891, Mr. Milliken, of the Committee on Public Buildings and Grounds, reported a bill with these same provisions in the House and Senator Morrill again introduced it into the Senate as an amendment to the sundry civil bill for 1892. The provisions were repeated in the bill introduced in the Fifty-second Congress by Senator Morrill, when the bill was agreed to by the Senate, but no action was taken in the House. In the Fifty-third Congress the same bill was introduced by Senator Morrill into the Senate, but not reported. It was again introduced into the Fifty-fourth Congress and later as an amendment. In the latter Congress Senator Morrill offered the identical provision as an amendment to the sundry civil bill for 1897. This was again agreed to by the Senate, but failed in the House and was eliminated in conference.

tions or by gifts from the people of the United States and foreign countries, but while the people may take just pride in what they feel is their own, collections gathered in this way are, as has just been observed, not only partially duplicated or triplicated, but are at the same time fragmentary and lacking in that completeness that comes by systematic work in bringing similar classes of objects together under a well-considered system.

The filling of the gaps just alluded to can only be brought about by the application of a purchasing fund. After repeated requests to Congress, a small appropriation was made at the last session for the special purpose of purchasing specimens, but the amount thus available is so limited and the deficiencies in the present collections are so great that it will be impracticable to add any entirely new series of objects at present, and the fund will be devoted to filling the gaps in existing series. It is hoped that Congress may hereafter grant larger sums for the acquisition of specimens.

The curators of the several departments of the Museum have continued during the past year the classification and arrangement of old and new material preparatory to its exhibition. The information gathered by the curators while examining and arranging specimens has in many cases been printed in the form of descriptive catalogues containing scientific information expressed in such untechnical language that visitors uninformed in the subject may readily understand the collections. The Secretary has constantly had in view the importance of the comprehensive labeling of objects placed on exhibition and he is gratified that much progress has been made in this direction, the museum having been well defined as a collection of instructive labels each illustrated by a well-selected specimen.

In the Appendix will be found a report giving details in regard to Museum work during the year, with reference to many important accessions. Mention may be made here of a few additions of special public interest, among which are a considerable number of memorials of the war with Spain and the Philippine insurrection. To the geological collections were added some interesting fossil animals secured from the fields of Wyoming, and a large amount of zoological material was collected in Cuba and Porto Rico. There has also been transferred to the Museum the extensive and very valuable series of vertebrate fossils collected by the late Professor Marsh during his connection with the United States Geological Survey. This collection aggregated five car-loads, and is particularly rich in specimens of the gigantic Dinosaurs, besides fifty skulls of Titanotherium, probably the best specimens in existence.

The general appearance of several of the Museum halls has been improved by replacing the old wooden floors by terrazzo pavements, and appropriation has been made for the completion of this much-needed improvement. Progress has also been made in furnishing with suitable exhibition cases the new galleries, which temporarily relieve a part of the congestion, and some interesting collections heretofore crowded into narrow limits have thus been less inadequately displayed, though the general aspect may yet be said with truth to be rather that of a storehouse than a museum.

BUREAU OF AMERICAN ETHNOLOGY.

The operations of the Bureau of American Ethnology were continued under the direction of Maj. J. W. Powell and his efficient assistants. The field work of the regular corps extended into Maine, New York, Minnesota, Wisconsin, Indian Territory, Oklahoma, California, Arizona, New Mexico, Cuba, Jamaica, Ontario, and Nova Scotia, while special work was done in other districts. The explorations and researches continue to yield valuable results in the form of contributions to the science of ethnology, while the collections made in connection with the work form an important tributary to the National Museum.

One of the reconnoissances of the year extended to the Antillean islands, which are supposed by students to have lain in the pathway of important aboriginal migrations, and data of consequence were obtained in the course of the work.

Among the recent acquisitions of the Bureau are two aboriginal vocabularies, both famed among students. One of these is the Trumbull Dictionary of the Natick (Massachusetts) Indian language, which was conveyed to the Bureau for publication through the intervention of Dr. Edward Everett Hale, vice-president of the American Antiquarian Society, the custodian of the manuscript. The other is a dictionary of the Maya language, known as the Diccionario de Motul, which has been in existence in manuscript form for centuries, and which is finally to be published through the agency of the Bureau.

Some practical importance attaches to the recent work of the Bureau in connection with aboriginal agriculture and crop plants. The investigation of the wild-rice industry, of the northern lake region especially, brings out a neglected phase of aboriginal industry, and at the same time directs attention to a promising natural resource.

One of the collaborators of the Bureau was detailed to the Government Board of the Pan-American Exposition, and made important collections in the Philippine Islands, some of which are designed for ultimate deposit in the Museum.

The details of the work of the Bureau are set forth fully in the Appendix to this report.

INTERNATIONAL EXCHANGES.

The free interchange of Government and scientific publications between this country and the governments and learned societies of other lands has grown to be one of the most important functions of the Smithsonian Institution. Great numbers of books are annually transmitted abroad and great quantities are received in exchange each year, the quantity handled during the past fiscal year aggregating 113,563 packages, weighing 409,991 pounds, an increase in weight of more than one-fourth over the previous year.

These exchanges are in no sense of a commercial nature, for no publications for sale are allowed transmission. More than one-half of the exchanges consist of Government documents, while the other half are publications exchanged between learned societies and men throughout the world. The International Exchange Bureau has salaried resident agents in London, Leipzig, and Budapest, and a large number of agents in various parts of the world who lend their services gratuitously. The correspondents who more or less regularly exchange publications through the Smithsonian Institution now aggregate 33,951, of which 7,721 are in the United States and the rest in foreign lands, extending even to the remotest corners of the world.

The expenses of the Exchange Service were for thirty years met entirely from the income of the Smithsonian Institution, but when public documents began to form so large a part of the transmissions as to become an unbearable drain on its resources, Congress began to make appropriations for the work, and the entire service, through international treaties, has since become chiefly (though not entirely) dependent on annual appropriations by Congress.

Publications from societies in this country intended for transmission abroad must be delivered at the Institution free of expense, and they are transmitted to foreign societies or individuals without charge. Packages received from abroad are distributed in this country under frank by registered mail.

The liberal policy of the United States Government in providing for the service is not, however, reciprocated abroad except by a few of the smaller countries. Great Britain, Germany, and Austria have never, while continuing the exchange service, subscribed to the Brussels treaty,[1] while France and Russia have contributed very mea-

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[1] The treaty concluded at Brussels, March 15, 1886, ratified by the President of the United States July 19, 1888, and of which ratifications were exchanged January 14, 1889, consists of ten articles, in which it is stipulated that there shall be established in each of the contracting States a bureau charged with the duty of exchanges, which shall embrace the official documents, parliamentary and administrative, which are published in the country of their origin, and works executed by order and at the expense of the Government; each bureau shall cause to be printed a list of the publi-

gerly toward the service. The United States, it will be observed, is the only first-class power which became a party to it, and it may perhaps be suggested as a not improbable reason for the abstention of such powers as England, France, Germany, or Russia, that the treaty would bind them to an exchange system chiefly with smaller powers who could not return as much as they received. This is an assumption only, but it refers to a condition which the writer was obliged to have in mind in his attempted negotiations.

The distribution of packages after they reach Europe and other foreign countries is, owing to the conditions just stated, slow and uncertain, except where the Institution has found it expedient to establish and maintain agencies for promoting its own interests. The returns from these countries, especially in the way of official documents, has moreover always been inadequate, due mainly, it would appear, to the lack of appreciation of the benefits to be gained thereby, but in part also to indifference. Efforts have constantly been made by the Institution to stimulate a greater interest in the subject among foreign countries, and representatives have been dispatched from time to time to explain the exchange methods and solicit a more liberal participation, but though something has been accomplished in this way, the relations have remained until recently practically as they were in the beginning.

In 1870 Professor Henry went to England and while there testified before an English Government scientific commission regarding the international exchange system, as it was then constituted in the exclusive charge of the Smithsonian Institution and carried on at its private expense.[1]

Later, Secretary Baird sent Mr. George H. Boehmer, in immediate charge of the Exchanges, to Europe on a similar errand, and twelve years after, the present Secretary sent Mr. William C. Winlock, curator of the Exchanges, to Leipsic to endeavor to improve the

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cations that it is able to place at the disposal of the contracting States, these several bureaus of exchange to arrange between themselves the number of copies which they may be able to demand and furnish; transmission shall be made direct from bureau to bureau; each State assumes the expense of packing and transportation to the place of destination, but when transmission shall be made by sea, special arrangements may be made as to the share of the expense that each State shall bear for transportation; the several bureaus shall serve in an officious capacity as intermediaries between the learned bodies and literary and scientific societies of the contracting States for the reception and transmission of their publications. The duties of the exchange will be confined to the mere transmission of the works of exchanges and will not in any manner take the initiative to bring about the establishment of reciprocal relations among correspondents.

The governments subscribing to this treaty are the United States of America, Belgium, Brazil, Italy, Portugal and the Algarves, Servia, Spain, and the Swiss Confederation. The representative of France subscribed to the treaty, but his action was not confirmed by the French Chambers.

[1] Journals, Board of Regents, Smithsonian Institution, 1879, p. 775.

exchange relations with Germany. On the occasion of Mr. Winlock's visit the Secretary was in Europe and called personally, with Mr. Eustis, the American minister, on the minister of public instruction in Paris, and secured from him a promise that he would endeavor to obtain from the Chambers something more than the inadequate sum, approximately $2,000, then provided for the French exchanges.

All these missions having proved only partially successful, however, and the condition of affairs with France having grown worse rather than better, the Secretary decided to give the matter his personal attention in an otherwise unofficial trip he was making to Europe for rest; a purpose with which this business interfered more than he had anticipated.

The endeavor to improve the relations with the exchanges in England, France and Germany commenced in the fiscal year covered by the present report, but extended in its latter portion into the present year. In order to avoid discontinuity, however, the Secretary presents the whole subject at this time.

On the 5th of June the Secretary wrote as follows:

JUNE 5, 1900.

SIR: I beg to bring to your attention a matter which has been the subject of much correspondence between the Department of State and the Smithsonian Institution during the past twenty years, and which is still in a most unsatisfactory condition. I allude to the system of international exchanges, which rests upon a treaty concluded at Brussels March 15, 1886, and which was signed by the President July 19, 1888.

To this treaty some of the most important nations of Europe have never agreed. England and Germany are not parties to it at all, while France and Russia conformed to a previous convention on the subject, but have never bound themselves to abide by the terms of the treaty. This works unfairly to this country, for whereas this Government presents one copy of every document published at the Government Printing Office to the national or legislative libraries of foreign countries, a most inadequate return is made; more especially from the countries of which I speak. Representatives of the Institution have been sent abroad on repeated occasions by my predecessors in this office, and by me, to try to regularize our exchanges. They have all failed, perhaps because as subordinate officers and not working with the advice of the Department, they could not exercise a proper influence.

Complaints are frequently made through bureaus of this Government of failures of the Exchange Service, due in reality wholly to its inability to control the actions of foreign Governments, and these at times are transmitted through the Department of State, which I have accordingly had occasion to already advise that the relations which exist with the principal foreign countries in this respect are not only unsatisfactory, but tend to grow worse.

I should be glad to know whether the Department deems it expedient at this time to obtain the adherence of England, Germany, and France to the Brussels treaty or to negotiate separate treaties, or whether any other step could be suggested to bring about a result so eminently desirable to the Government service, to the Library of Congress, and to this Institution.

If the Department deem it expedient to take up the matter this summer, I am prepared to go abroad without cost to the Department, and if I could be useful by furnishing any ambassador or minister at the posts mentioned with any detailed information he may desire I should be very glad to put my services at its disposal.

I have the honor to be, sir, your obedient servant,

S. P. LANGLEY, *Secretary.*

The SECRETARY OF STATE,
Washington, D. C.

To the above communication the following reply was received:

DEPARTMENT OF STATE,
Washington, June 20, 1900.

SIR: I have the honor to acknowledge the receipt of your letter of June 5, in which you bring to the attention of this Department the unsatisfactory condition of the system of international exchanges which rests upon a treaty concluded at Brussels March 15, 1886. You state that some of the most important nations of Europe have never agreed to this treaty, England and Germany not being parties to it at all, while France and Russia conform to the provisions of the convention on the subject but have never bound themselves to abide by the terms of the treaty. You point out that this works unfairly to this country, which receives an inadequate return for the documents which it sends out. You call attention to the failure of previous attempts to ameliorate the existing state of things. You inquire whether or not it seems expedient to this Department at this time to obtain the adherence of England, Germany, and France to the provisions of the treaty or to negotiate separate treaties, or whether or not any other system could be suggested to bring about a result so eminently desirable to the Government service, to the Library of Congress, and the Smithsonian Institution.

You state that you are about to proceed abroad, and that you would be disposed to place your services at the disposal of the Department for the execution of plans for the improvement of the Exchange Service. In reply to your generous proposition I have the honor to say that it does not seem expedient to endeavor to urge upon England, Germany, and France adhesion to the Brussels treaty, as it is probable that they have what appear to them sufficient reasons for not becoming signatories to this convention. It is possible that one of their objections is that adherence to the convention would require them to furnish complete sets of valuable publications to the smaller and less important governments in exchange for publications which they may deem of inconsiderable value. At all events it does not seem practicable to endeaver to overcome their disinclination to become participants in the arrangements of the treaty.

It is, however, eminently proper that during your contemplated visit to Europe you should lay this matter clearly before the diplomatic representatives of the United States in the capitals where your journey may call you, and perhaps have personal conversations with those officers of the foreign governments to which reference has been made, who may be able to facilitate the sending of publications of those governments in exchange for those sent from the United States. Such arrangements as will secure to this country the full benefits which might be secured through the adherence of England, Germany, and France to the Brussels treaty may doubtless be obtained in this manner, which would be found, perhaps, less objectionable to them than a formal adherence to the convention, against which, for some reason, they seem to entertain a prejudice.

I have the honor to be, sir, your obedient servant,

John Hay.

Hon. S. P. Langley,
Secretary of the Smithsonian Institution,
Washington, D. C.

The results of the Secretary's labors are summarized under the head of each country separately, as follows:

ENGLAND.

On July 18 the Secretary presented to the embassy a written statement concerning the condition of exchange matters between the United States and Great Britain, a copy of which follows:

London, England, *July 18, 1900.*

Sir: The Smithsonian Institution, consisting of an establishment composed of the President of the United States, the Vice-President, the Chief Justice, and the heads of the Departments, was founded by an act of Congress in the year 1846, with functions rather general than local in their character, it being described in the words of the act as "for the increase and diffusion of knowledge among men."

It has, as a part of these functions, at all times promoted the intercommunication of literary and scientific matter between the United States and Great Britain, as well as with other nations, and this system of literary and scientific exchange, while officially promoted by the Government of the United States since the first half of the present century, has more recently been extended by the legislation of which I now speak.

With the approval of the Secretary of State, I have then the honor to address you the following memoranda concerning the exchange of official and other publications between the United States and Great Britain, and to respectfully ask your interest in concluding a long-needed arrangement which shall provide on the part of the British Government for action reciprocal to that of the United States, regarding, first, exchanges of official publications of the Government, and, second, for scientific and literary exchanges.

MEMORANDA CONCERNING EXCHANGES BETWEEN THE UNITED STATES AND GREAT BRITAIN.

1. *Government exchanges.*

On March 2, 1867, the following joint resolution of Congress was approved by the President:

"*Resolved by the Senate and House of Representatives of the United States of America in Congress assembled,* That fifty copies of all documents hereafter printed by order of either House of Congress, and fifty copies additional of all documents printed in excess of the usual number, together with fifty copies of each publication issued by any department or bureau of the Government, be placed at the disposal of the Joint Committee on the Library, who shall exchange the same, through the agency of the Smithsonian Institution, for such works published in foreign countries, and especially by foreign governments, as may be deemed by said committee an equivalent; said works to be deposited in the Library of Congress."

In accordance with this, the United States has since that time presented, through the Smithsonian Institution, a complete set of all its official publications to the British Museum, for the British Government.

In 1886, Belgium, Brazil, Italy, Portugal, Servia, and Spain entered into a convention at Brussels, to which the United States was a party, by which they agreed to reciprocal arrangements as to the manner of exchanging both official and literary and scientific publications, as well as to the expenses of shipment and the establishment of offices.

To this convention Great Britain did not become a party.

On October 1, 1875, the Institution addressed, through the proper channel, a request to the English Government to arrange for an adequate return on its part of its own publications for those sent by the United States Government. Lord Derby, however, in a letter of March 1, 1877, requested the American minister to "inform Professor Henry, the Secretary of the Smithsonian Institution, that Her Majesty is grateful for the offer made by the Smithsonian Institution, but are not prepared to enter into an arrangement for the unlimited exchange of documents suggested in his letter to you."

Various departments and offices of the British Government have since sent in exchange British Government publications, but only lately in a systematic manner and in quantity that would be deemed an equivalent for those of the United States.

In the twenty-three years which have elapsed since Lord Derby's letter was written the already considerable sendings of the United States Government to England have been increased more than threefold, and it seems now desirable that the British Government shall (if it does not wish to become a party to the Brussels treaty) establish some suitable bureau or office charged with the duty of collecting all publications not confidential, issued by Her Majesty's Government, to be transmitted to the United States in exchange for the set of publications now forwarded to the British Museum. The Institution has of late received British official publications from Her Majesty's stationery office.

2. Scientific and literary exchanges.

Since its foundation the Smithsonian Institution has conducted a system of the exchange of literary and scientific publications voluntarily presented by institutions or individuals in the United States to others in Great Britain and her colonies, and reciprocally. This international system has proven itself of the greatest value to literary and scientific men everywhere, and it has been conducted through the established agencies and correspondents of the Institution free of cost to such institutions and individuals in Great Britain and her colonies.

This system was formally recognized in convention in Brussels with regard to the participation above referred to, but in this case Great Britain has taken no steps to reciprocate.

Up to the present time, nevertheless, the Smithsonian Institution, rather than interrupt this useful work, and while still acting for the United States Government, has maintained in London an agency transacting all the business for scientific institutions and individuals within Great Britain that it could be expected the English Government itself would transact.

It is desired that, in addition to the arrangement for conducting the exchange of Government official publications above referred to, or as a part of it, the Government of Great Britain shall establish such a bureau to receive such literary and scientific exchanges within the British Empire as the Smithsonian Institution does for Great Britain within the United States, and that the British Government shall agree to pay the cost of delivery at the port of New York or San Francisco on all matter of this kind, the United States Government agreeing to pay all the costs of delivery on similar matter either at the ports of Liverpool or Southampton.

I beg to add, in anticipation of any possible inquiry, that as regards the literary and scientific exchanges, not only are those of a mercantile character not admitted, but that such are rarely tendered even, and that, so far as can be gathered from an experience of somewhat over fifty years, the great advantages that this system offers to literary and scientific men are unlikely to be abused.

I beg to inclose with this, for your convenience, a copy of a recent letter from the honorable the Secretary of State, a copy of the Brussels treaty referred to, and a copy of the History of the Smithsonian Exchange System between the years 1849 and 1881.

I have the honor to be, very respectfully, your obedient servant,

S. P. Langley,
Secretary of the Smithsonian Institution.

The Hon. Joseph H. Choate,
American Ambassador to the Court of St. James,
London, England.

The ambassador, Mr. Choate, and the first secretary of the embassy, Mr. White, used every available means to bring the matter to the attention of the foreign office, but it was not until October 9, after the Secretary's return from France and Germany, that he was able to arrange an interview with Mr. Villiers, the under secretary for foreign affairs. In the course of this conversation, Mr. Oakes and Mr. Plowman, the assistant comptroller of the Secretary's office, were called in for consultation. Mr. Villiers and his associates seemed to doubt if the English Government would undertake to act as a medium for the forwarding and distribution of scientific exchanges, and stated that the matter had already been referred to the treasury. The Secretary represented that we did not want to involve them in an expenditure, as they seemed to apprehend, but to have them meet us halfway, and recognize the utility of the work which was now being carried on by affording it an official sanction, such as our Government had already done, thus giving to them something which they were not giving to us. The Secretary laid stress upon the fact that we were not asking them to enter on anything resembling the general reciprocity of the

Brussels treaty, but to arrange for the exchange of such things with the United States alone.

The Secretary found them disposed to hesitate as to recommending their Government to take up the subject of the scientific exchanges, or to undertake to furnish a complete series of its publications, embracing all such works as are published by booksellers with the aid of grants or subscriptions from the Government.

This last provision was objected to, but it seems to be easily modifiable. The interview was unproductive of immediate results, but the matter was held open for further consideration, and the Secretary stated that it was the intention of the Institution to write more particularly as to exactly what it desired, and to propose only such terms as reciprocal justice seemed to call for.

FRANCE.

As an introduction to my efforts to bring the subject of my visit to France before the ministry, I addressed a letter to the United States embassy, setting forth the facts and the objects which it was my purpose to accomplish. A copy of this letter follows:

JULY 28, 1900.

SIR: The Smithsonian Institution, consisting of an establishment composed of the President of the United States, the Vice-President, the Chief Justice, and the heads of departments, was founded by an act of Congress in the year 1846, with functions rather general than local in their character, it being described in the words of the act as "for the increase and diffusion of knowledge among men."

It has as a part of these functions at all times promoted the intercommunication of literary and scientific matter between the United States and France, as well as with other nations, and this system of literary and scientific exchange, while officially promoted by the Government of the United States since the first half of the present century, has more recently been extended by the legislation of which I now speak.

With the approval of the Secretary of State, I have the honor to address you the following memoranda concerning the exchange of official and other publications between the United States and France, and to specially ask your interest in concluding a long-needed arrangement which shall provide, on the part of the French Government, for action reciprocal to that of the United States concerning these two classes, and regarding, first, exchanges of official publications of the Government, and, second, for scientific and literary exchanges conducted by the Government.

MEMORANDA CONCERNING EXCHANGES BETWEEN THE UNITED STATES AND FRANCE.

1. *Exchange of Government publications.*

On March 2, 1867, the following joint resolution was approved by the President:

"*Resolved by the Senate and House of Representatives of the United States of America in Congress assembled*, That fifty copies of all documents hereafter printed by order of either House of Congress and fifty copies additional of all documents printed in excess of the usual number, together with fifty copies of each publication issued by any department or bureau of the Government, be placed at the disposal of the Joint Committee on the Library, who shall exchange the same, through the agency of the Smithsonian Institution, for such works published in foreign countries, and especially by foreign governments, as may be deemed by said committee an equivalent; said works to be deposited in the Library of Congress."

In accordance with this the United States has since that time presented, through the Smithsonian Institution, a complete set of its official publications to the Bibliotheque Nationale, Paris, through the Bureau des Échanges Internationaux.

In 1886, Belgium, Brazil, Italy, Portugal, Servia, and Spain entered into a convention at Brussels to which the United States was a party, by which they agreed to reciprocal arrangements as to the manner of exchanging both official and literary and scientific publications as well as the expenses of shipment and the establishment of offices.

To this convention France was a signatory, but did not eventually become a party.

The French Government, however, appears to have established a bureau, "des Échanges Internationaux."

On February 8, 1879, the Smithsonian Institution addressed a request to Baron de Vatteville, Commissionaire des Échanges Internationaux, requesting * * * "not merely the special publications of some of the scientific bureaus, but a series of everything published by the State, as complete as that which we send, to include the records of the legislature of the Republic, its reports upon education, statistics, commerce, navigation, topographical and geological explorations, etc."

The returns made on account of this appeal have never been satisfactory, and while the various departments and offices of the French Government have from time to time sent in exchange some French Government publications, the receipts have been wholly inadequate, being less than one-fifth of the amount sent by the United States, and consisting of ordinary reports, with few publications of intrinsic value.

In this connection, I beg to state that in June, 1895, accompanied by the then American minister, Mr. Eustis, I visited the Ministre de l'Instruction Publique et des Beaux Arts to obtain an improvement of the International Exchange System in this particular, and also with regard to the scientific and literary exchanges mentioned. He then promised the American minister that he would apply to the French Chambers for an additional grant for this bureau. He also promised that he would demand an act for the better doing of this and to provide means of sending these publications more frequently, at least every month. He also promised that a separate set would be sent to the library of the Institution.

I have received an official and written statement from Mr. Eustis to the same effect.

You will see from the inclosed copy of a letter written on the part of the minister of foreign affairs by the minister plenipotentiary on July 29, 1895, that it is officially stated that the Ministre de l'Instruction Publique et des Beaux Arts has resolved to ask of Parliament a "majoration" of credit for the International Exchanges, and, further than this, that he intends to have an arrangement with the different ministerial departments in order that everything that the Government publishes shall be sent.

I particularly call your attention to this expression of intended official action, which, so far as I know, has had no result.

It has been understood that this was due primarily to the wholly inadequate appropriation of 10,000 francs, which appears to be all that is given by the French Government for this service, as compared with 120,000 francs ($24,000) appropriated by our own Government for a similar service.

It seems, then, desirable that the French Government shall, if it does not desire to become a party to the Brussels treaty, undertake to make, through some designated channel, delivery of all its official publications through the bureau in question in exchange for the set of publications now forwarded to the Bibliotheque Nationale.

2. *Scientific and literary exchanges.*

Since its foundation the Smithsonian Institution has conducted a system for the exchange of literary and scientific publications voluntarily presented by institutions and individuals in the United States to others in France and her colonies, and reciprocally. This international system has proved itself of the greatest value to literary and scientific men everywhere, and it has been conducted on the part of the United States Government by the Smithsonian Institution with the understood cooperation of the French Government, the Institution delivering the publications in question at the port of Havre at the cost of the United States Government. There has, however, been much complaint from the correspondents of the Institution of the delay of the delivery of publications forwarded from America to France and from France to America, a delay which arises in French territory and from causes beyond our control. The French Government now delivers French literary and scientific publications at the port of New York, and the Institution punctually distributes these at its own cost.

I beg to add, in anticipation of any possible inquiry, that as regards the literary and scientific exchanges, not only are those of a mercantile character not admitted, but that such are rarely tendered even; and that so far as can be gathered from an experience of somewhat over fifty years, the great advantages that this system offers to literary and scientific men are unlikely to be abused.

I beg to inclose with this for your convenience a copy of a recent letter from the honorable the Secretary of State, a copy of the Brussels treaty referred to, and a copy of History of the Smithsonian Exchange System between the years 1849 and 1881.

I have the honor to be, very respectfully, your obedient servant,

S. P. LANGLEY,
Secretary of the Smithsonian Institution.

HENRY VIGNAUD, ESQ.,
Chargé d'Affaires, United States Embassy,
Avenue Kleber, Paris.

In spite of the good will of the embassy, the Secretary found it impossible to secure an immediate interview with the minister of public instruction, and as he did not wish to remain in Paris indefinitely he proceeded to Germany, and upon his return to Paris in September it was finally arranged that he should call on the representative of the minister, as the minister himself was absent. The Secretary did so in company with Mr. Henry Vignaud, the first secretary of the embassy, but in the continued absence of the minister the Secretary was referred to Monsieur Louis Liard, chief of the libraries of France, to whose charge has recently been transferred the matter of the Exchanges, and on whose recommendation the minister of public instruction, the Secretary was assured, would almost certainly act.

The Secretary saw Monsieur Liard, who stated that the exchange affairs had only recently come into his own department, and while looking up the matter of appropriations the Secretary told him that at a time when the French appropriation for the exchanges was 10,000 francs per annum the minister had explicitly promised him, in the presence of the American minister, Mr. Eustis, that he would ask the Chambers to increase the amount, instead of which, Mr. Liard informed the Secretary, the appropriation had been reduced to 6,000 francs. He then promised that there would be no further reduction, but, on the contrary, that there would be an increase. The Secretary spoke to him privately about the Smithsonian Institution, and told him the difficulties that were experienced in France about the delay in transmitting parcels to the interior, which he promised should be looked after.

As a result of the conversation above noted, the Secretary believes that there is a better prospect of an ultimate improvement in the French exchange service than he has ever previously allowed himself to feel.

GERMANY.

A letter of similar tenor to that already cited to the American ambassador at Paris was written to the United States ambassador in Berlin, in which it was stated, however, that the United States Government was sending through the Smithsonian Institution six entire sets of its publications to the German Empire, and that various departments and offices of the German Government have sent their publications in exchange, but not in quantity that would be deemed an equivalent for those of the United States. It was further stated that it seemed desirable that the German Government should, if it did not wish to become a party to the Brussels treaty, establish some suitable bureau or office, charged with the duty of collecting all publications, not confidential, issued by the Imperial Government, or by the governments of Baden, Bavaria, Saxony, and Württemberg, to be transmitted to the United States in exchange for the six sets of publications now forwarded to Germany for those countries.

The embassy acknowledged the receipt of the Secretary's letter in the following terms:

EMBASSY OF THE UNITED STATES OF AMERICA,
Berlin, July 25, 1900.

SIR: Before going on leave Mr. White turned over to me your letter of the 20th instant, the receipt of which has, I believe, already been acknowledged. Mr. White did not, however, inform me as to what he had written you, and now that he will not be here I do not know if it is still your intention to come to Berlin. I therefore write to say that I shall be here through the summer, and will gladly do anything in my power to be of service in the matter in question. The Department of State, under date of the 21st ultimo, had already instructed the Embassy in regard to its assisting you.

As you are no doubt aware, German (Imperial, Prussian, Bavarian, Saxon, Württemberg, or Baden) public documents are not distributed gratuitously as freely as are similar documents in the United States, and that if any ministry or other similar office wishes to have more than the limited number of such documents as are regularly placed at its disposal it must purchase them from the publisher. You also, of course, know that as yet Germany has no central distributing office similar to that of the Smithsonian Institution, nor does any such office exist in any of the several federated states. Moreover, I have not heard of any intention to establish any such office or offices, and I do not know of any central authority who (which) might be interested in maintaining an exchange of public documents with all six of the institutions with which you now exchange. Would it not be practicable to correspond with the heads of each of these six institutions, making each one responsible for your receiving a proper return of the documents of the Empire or the individual State which you consider him to represent?

Awaiting a further communication from you before taking any action, I am, sir, your obedient servant,

JOHN B. JACKSON,
Chargé d'Affaires.

HON. S. P. LANGLEY,
Secretary of the Smithsonian Institution,
Care of American Embassy, London.

Upon the Secretary's arrival at Berlin he found a note at the embassy from Mr. Herbert Putnam, the Librarian of Congress, which, as it bears an important part in the work, is quoted in full:

HOTEL BRISTOL,
Berlin, August 11, 1900.

MY DEAR DR. LANGLEY: I brought to Berlin notes of introduction from the German ambassador at Washington to the imperial minister of the interior and to the Prussian Kultus-Minister and had intended to approach these officials in the matter of international exchanges.

Learning, however, at the American embassy that you are to visit Berlin on a similar mission, I have contented myself with the mere delivery of my credentials, accompanying them, however, with a note, in which I intimated the probability of your visit and urged the importance of your mission to the interests which I represent, including the Congress of the United States.

I brought with me a memorandum (incomplete doubtless, yet suggestive) of the German imperial and of the Prussian serial documents issued, with a note of those now in the Library of Congress. These lists have been left at the embassy for you to use in case they may seem calculated to be of service. They may, if you think best, be left with the authorities here. If this seem inadvisable, they will be forwarded from the embassy to the Library of Congress. In such lists I am careful to disclaim accuracy or completeness.

With best wishes, faithfully yours,

HERBERT PUTNAM,
Librarian of Congress.

MR. S. P. LANGLEY,
Secretary, etc.

Upon reviewing the matter carefully with Mr. Jackson, the Secretary was informed that there was no central authority in Germany, not even the chancellor of the Empire, who could deal with the exchange question. Each of the different States must be appealed to separately, and the minor ones are jealous of any appearance of interference from federal authorities. There seems to be positively no way to get official action short of the Reichstag, which could only provide the money, but could not insure that the matter would be accepted by the separate states any more than the action of the United States Congress in appropriating for our exchanges can bind the separate States of the Union.

After my interview, Mr. Jackson kindly called on an official who represented Prince Hohenlohe in his absence. This officer, however, could not take upon himself to make even a suggestion in the absence of Prince Hohenlohe as to what action might be taken.

The Secretary called at the Parliament House and consulted at length with Dr. Muller, the librarian, who agreed that the only official who it could be even remotely hoped would do anything with regard to exchanges would be the chancellor. The only power that could act authoritatively is the German Parliament itself, and Dr. Muller promised to interest himself in having the matter presented before it in November, in the hope of some effectual action.

In this connection the Secretary may state that he arrived in Berlin at a most inopportune time to transact the business he had in hand, inasmuch as only two out of the sixteen ministers were in the city, but that the kindness of the embassy represented by Mr. Jackson did everything for him that could be done under such condition.

NATIONAL ZOOLOGICAL PARK.

The act of Congress establishing the National Zoological Park placed it under the direction of the Regents of the Smithsonian Institution. It occupies about 170 acres in a region along Rock Creek valley, which is probably the most beautiful in its diversified natural features of any similar park in any capital of the world. The objects of the park have been abundantly set forth at other times. Though essentially national and not local, it is intended to have, in connection with other and remote national parks in the West, a representation of all our North American animals which can be safely transported here, and it is situated in the national capital to serve as a constant object lesson of what Congress may do.

In addition to this, its primary function, the park receives animals which are sent from various parts of the world by the officers of the Army and Navy and other agents of the Government, and an extremely limited number is added to its collection by purchase.

The present Secretary, who was instrumental in asking the interest of Congress in originally securing the fine tract of land embraced within the park, has taken a continued interest in personally superintending the details of its embellishment, always having it as a guiding principle in his treatment of its features to leave nature largely to herself, and not to attempt to beautify what is already beautiful, but to expend the means at his command in providing the necessary buildings for holding the collections and in making good roads which shall make every part of this beautiful region accessible.

The extremely limited appropriations allowed by Congress have made it almost impossible to carry out the original programme of procuring a large collection of specimens of our native animals. Even as it is, however, the collection is believed to be an extremely interesting one, notwithstanding the limited means.

The present value of buildings, roadways, and other improvements is estimated at about $150,000, and there are 839 animals, small and great, in the collection. The Superintendent's report, on another page, mentions a number of improvements made during the year, including the completion of the antelope house, new paddocks and sheds for moose, caribou, fallow deer, and arctic foxes, fence for buffalo paddocks, temporary house for birds, and the continuation of the driveway along Rock Creek.

The western boundary of the park, for some years past unsettled owing to the provisions of the highway act, has been finally determined during the year. The terms of the legislation concerning this boundary will be found in the superintendent's report, accompanied by an illustrative map. Its effect may be stated briefly as running an avenue 90 feet wide through the highest portion of the land of the park, where it is objectionable as disfiguring the landscape. It takes away for this purpose about 46,000 square feet, and the change involves the addition of 66,500 feet of lower lying and less desirable land. So far, it is not in the interest of the park that this change should have been made, but the legislation was not opposed, for reasons of general public interest, and also because, if any avenue was to be here, it had better be of this width to move back the buildings which will doubtless eventually be placed here, so that they may not immediately dominate that portion of the park which was especially intended to be secluded.

By act of Congress, March 3, 1899, provision was made for widening the Adams Mill road entrance to the park and placing under the control of the park, not only the portion of the road within the park, but that exterior to it. As regards the portion exterior to the park, its control as a residential street presented serious difficulties, and the Secretary was willing to see this part placed by subsequent legislation under the control of the Commissioners of the District of Columbia.

As a result of the circular sent abroad to officers of the United States, mentioned in the last report of the Secretary, the Zoological Park has secured some valuable additions and has arranged for future acquisitions. An account of these will be found in the report of the superintendent.

Among the imperative needs of the park are a suitable bird and reptile house, a house for small mammals, and a building for the aquarium.

Earnest efforts have been made to obtain from Alaska one or more specimens of the great Kodiak bear, but so far without success, and unless Congress furnish means to do so within a very brief time, this, the largest carnivorous animal of the world, will become extinct.

ASTROPHYSICAL OBSERVATORY.

It is gratifying to be able to state that the first and long-delayed volume of Annals of the Astrophysical Observatory is now about to be issued. This volume is devoted primarily, though not exclusively, to the investigation of the infra-red solar spectrum, its absorption lines, and its variations in terrestrial absorption. This research, and the development of the sensitive bolographic apparatus with which it has been carried on, have largely occupied the Astrophysical Observatory since its foundation, and are a continuation of researches in which the writer was engaged for many years at the Allegheny Observatory. The high degree of sensitiveness and accuracy which have now been reached in the bolometric apparatus of the Astrophysical Observatory, and the still greater progress in this direction which, as will be seen in the detailed report of the aid acting in charge, is now being achieved, place the Observatory in a position to enter new fields of work from which it has hitherto been barred by the lack of sufficiently sensitive appliances.

At the close of last year an application was made to Congress for a special appropriation to observe the total solar eclipse of May 28, 1900, in this country.

In view of the fact that the Observatory possessed a considerable quantity of apparatus which could be usefully employed in the expedition, and that the money could be chiefly allotted to the direct observations, the amount asked for was only $4,000, and this, which was granted by Congress, has been found, with strict economy, to be sufficient.

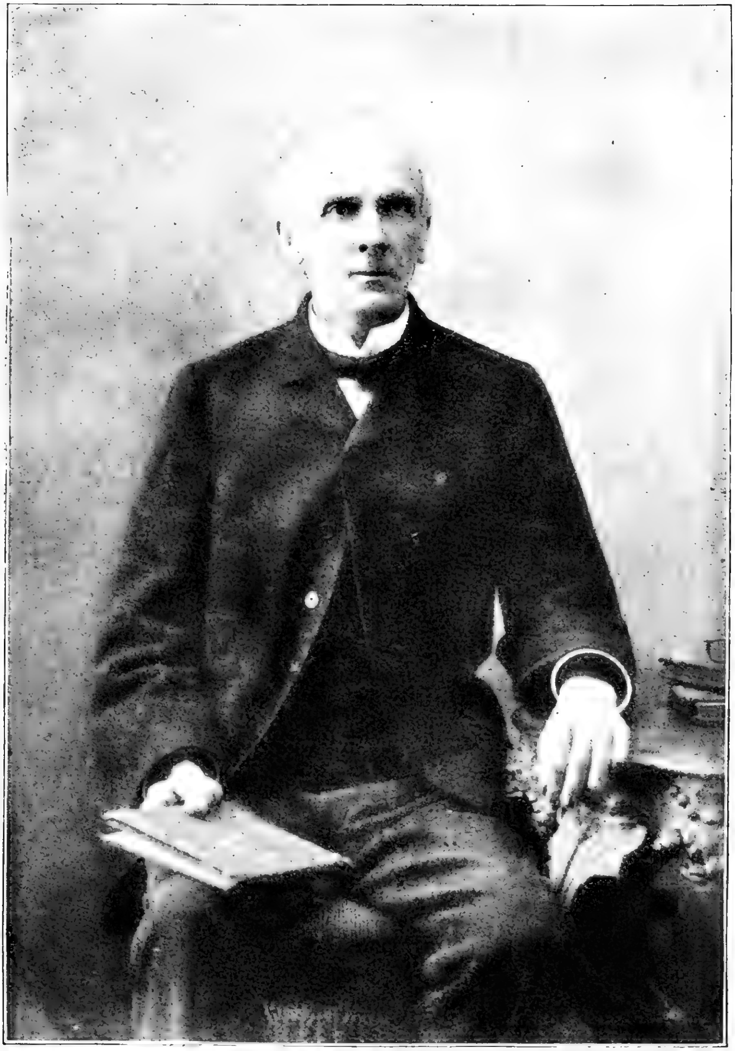
The appropriation was made on February 9, and preparations were immediately commenced for a rehearsal of the actual observations, which were to take place later. In doing this the Institution, which had borrowed, through the great kindness of Prof. E. C. Pickering, Director of the Harvard University Observatory, an achromatic lens of 12 inches aperture and 135 feet focus, installed this with numerous other pieces of apparatus in the open space immediately south and west of the Astrophysical Observatory, and all the material of the future camp was placed in position there and the observers accustomed to such portions of the work as could be undertaken in rehearsal.

The chief object of the expedition was intended to be the securing of a number of photographs of the corona on different scales, and especially on the unprecedentedly large scale afforded by the lunar image of the 135-foot lens, which was about 15 inches in diameter. This lens was, of course, placed so as to direct its beams horizontally, the light being fed into it by a "coelostat," the only considerable instrument ordered specially for the expedition.

A lens of 5 inches aperture and 38 feet focus, kindly lent by Professor Young, of Princeton, was placed in position to point at the sun, and the equatorial portion of the coelostat was made to carry a photographic telescope of 6 inches aperture and 7 feet focus for obtaining photographs of the portion of the corona near the sun. In addition to this, special preparation was made for a photographic search for intramercurial planets, which will be described later.

The question of the heat of the inner corona is an interesting one, about which testimony differs, for although numerous attempts have been made to measure it, they have been insufficient to give assurances of any positive result having been reached, particularly as some of them have been in comparatively inexperienced hands. The task of securing some authentic record of this with the bolometer the Secretary assigned to Mr. C. G. Abbot, who has had long experience in the use of the instrument and who was liberally supplied with every accessory that could be transported to the field, including the great siderostat made by Grubb, which alone weighs many thousand pounds.

It had at first been intended to establish the camp at Winton, North Carolina, but after anxious consideration, Wadesboro, in the same State, was substituted, and Mr. Abbot, with some of his immediate assistants, and all the heavier apparatus, left for that place on the 3d of May. Owing to the kindness of the United States Coast and



WILLIAM PRESTON JOHNSTON,

Regent of the Smithsonian Institution. Born 1831, died 1899.

Geodetic Survey, Mr. G. R. Putnam was detailed to make the requisite determinations of latitude and longitude and also to determine the position of the great horizontal telescope and the like accessory features, and most acceptable service was rendered by him.

So full an account of the eclipse is given in Mr. Abbot's report that it is only necessary to say here that the observations were almost uniformly successful. A considerable number of photographs of the corona were secured, some of which are upon an unprecedentedly large scale, and these, it is believed, will be of value in investigations of the nature of this still enigmatical solar appendage. A photographic search for hitherto unrecognized objects near the sun developed the fact that even in an ordinary sky, in an eclipse in which the reflected sunlight was brighter than usual, stars as small as the 8.3 magnitude could be secured.

The apparatus was designed not so much for this, however, as for the obtaining evidence of possible intramercurial planets, but upon this latter point we have not yet obtained any certainty. Certain suspicious objects are found on the plates, but unfortunately observations of the same kind at other stations were unsuccessful, so that there is nothing with which to compare them. Studies are still going on, however, and it is possible that this part of the observations may yet yield results of interest.

The delicate and difficult observations upon the heat of the inner corona were made by means of the bolometer, and appear to have been quite successful, being perhaps the first trustworthy observations of the kind; and, as will be seen in the more detailed report, these lend some additional weight to the view that the corona is something analogous to an electric phenomenon.

NECROLOGY.

WILLIAM PRESTON JOHNSTON.

At a meeting of the Regents on January 24, 1900, Dr. Angell submitted the following minute to go upon the records in regard to the death of William Preston Johnston, president of Tulane University:

President Johnston died at Lexington, Virginia, on July 16, 1899, in the sixty-ninth year of his age. He was born in Louisville, Kentucky, January 5, 1831. His father, the distinguished officer, General Albert Sidney Johnston, was of New England descent; his mother was of the Preston family, long conspicuous in Virginia and Kentucky. Our late colleague, while a student in school and college, gave promise of his future eminence. After graduation at Yale College he studied law and entered on the practice of his profession at Louisville. But his dominant taste even then was for letters rather than for law. On the outbreak of the civil war, like his father, he entered the

Southern army. Most of his service was rendered on staff duty, and was regarded by his superiors as of the highest value.

Soon after General Lee was called to the presidency of Washington and Lee University, he assigned to Mr. Johnston the chair of literature and history in that institution. The duties were most congenial to him, and with marked success he held the position for ten years. While there he wrote the well-known biography of his father.

In 1880 he was called to the presidency of the University of Louisiana at Baton Rouge. With characteristic vigor he set about the task of lifting it from its apparently moribund condition. When in 1883 Paul Tulane set apart a most generous sum for the endowment of the institution which now bears his name, Colonel Johnston was asked to organize the new university. With much tact and wisdom, he, with others, made a successful endeavor to merge the State University and the Tulane University in one institution, over which he presided with signal efficiency to the day of his death. Tulane University comprises several departments, and holds a most conspicuous position among the universities of the South. It is the general verdict of those most familiar with its history that its success has been largely, if not mainly, due to the wisdom, learning, and influence of our lamented colleague.

President Johnston was not only a successful administrator, but he was also a writer of decided literary merit. His essays on literary subjects and his occasional addresses are of a high type of excellence. He has also printed at least two volumes of poems that breathe the deeply religious spirit which was one of the marked characteristics of the author.

President Johnston was held in the highest esteem by all who knew him on account of his dignity, sincerity, and elevation of spirit.

For several years past he has had to contend in the discharge of his important official duties with a serious bronchial affection which was very debilitating. But his fidelity to his trusts and his invincible energy held him firmly at his post until the end of his days.

He was deeply interested in the work of the Smithsonian Institution. We wish hereby to record the expression of our sense of the great loss we have sustained in his death.

The following resolutions were then adopted by the Board:

WHEREAS the Regents of the Smithsonian Institution are called upon to mourn the death, on July 16, 1899, of William Preston Johnston, LL. D., president of Tulane University, and a member of this board since 1892,

Be it resolved, That the Regents desire to place on record an expression of their sense of the great loss they have suffered in the decease of their esteemed colleague, their high appreciation of his profound scholarship and literary gifts, of his wise and conspicuous influence in the promotion of sound learning, of his brilliant and useful career as a teacher and as an administrator of universities, of his sincere devotion to the interests of this Institution, and of his pure and noble character, which commanded the respect and affection of all who knew him.

Resolved, That these resolutions be placed upon the records of the Institution, that a copy be communicated to the family of President Johnston, and that we, the Regents, convey the assurance of deep sympathy with them in their affliction.

GARRET A. HOBART,

Regent of the Smithsonian Institution. Born 1844, died 1899.

GARRET A. HOBART.

At the same meeting of the Regents Senator Platt announced the death on November 21, 1899, of Vice-President Garret A. Hobart, a Regent of the Institution, and said:

As an associate and friend of the deceased Vice-President, Garret A. Hobart, I wish to speak briefly of him and of his life.

He was taken away from us, from the country which honored him and which he greatly honored, in the prime of his manhood and the height of his usefulness. Though born without the accessory of fortune, his ancestry was of the best and his blood the purest. A poor boy, facing the world alone, he wrought out a career indeed enviable, furnishing one more of the many examples of what a boy may become in the estimation of all under our republican institutions. He possessed in a large degree the only ambition worth cherishing—the ambition to make the most of himself, that he might be most useful. Like other self-made men, he struggled for an education and for a place among his fellow-men. Nature endowed him with its most generous gifts—sagacity, manly force, cordiality, charity, intellectual and moral attributes. Few men have possessed in a greater degree the capacity to make and retain friends, ready to serve him and to promote and advance his purposes.

It is often said that to succeed one must make enemies. Garret A. Hobart was an exception to this rule. He had no enemies, but "troops of friends." Of him it can be said more truly than of anyone I have ever known—

> None knew thee but to love thee,
> Nor named thee but to praise.

Office and honor sought him more than he sought them. He brought to the office of Vice-President a new dignity and new usefulness. He achieved wealth only to bestow the blessings which wealth gives the opportunity to scatter. In the life of such a man we are all ennobled; in his death we are all bereaved.

He seems like one lent to our social, political, and business life as an uplifting force and as an example to be emulated. Such men do not really die; they live, because they have impressed themselves upon the history of their age.

I think it most proper that resolutions expressing our unstinted admiration of our departed associate should be placed upon the records, and that we communicate to his widow and family our most sincere and heartfelt sympathy.

The following resolutions were adopted by the Board:

Resolved, That in the death of Garret A. Hobart, Vice-President of the United States, and ex officio a member of the Board of Regents, the Institution has sustained a severe loss and the members of the Board a personal bereavement.

Resolved, That we desire to place on record our appreciation of his services as a Regent of the Smithsonian Institution and our tribute of regard for his personal character and worth, as well as our intense sympathy for his widow and family, to whom his loss is most irreparable. Mr. Hobart was a man of rarest quality, a typical and thorough

American, successful in all that he undertook, characteristically of a broad and generous nature, a self-made man in the best sense of the term, a complete man in all his developments; a Vice-President of the United States most loved and honored and most conspicuous in the discharge of official duties, enjoying the friendship of the President, of the Senate, of all with whom he associated, and of the people of the United States. While we mourn his loss we admire his life and his character.

Resolved, That these resolutions be placed upon the records of the Institution and an engrossed copy thereof transmitted to his widow by the Secretary.

Respectfully submitted.

S. P. LANGLEY,
Secretary of the Smithsonian Institution.

APPENDIX TO THE SECRETARY'S REPORT.

APPENDIX I.

REPORT ON THE UNITED STATES NATIONAL MUSEUM.

SIR: I have the honor to report as follows regarding the condition and operations of the National Museum during the year ending June 30, 1900:

Organization and staff.—The organization of the Museum remains the same as during the past two years, comprising, beside the administrative offices, three scientific departments—anthropology, biology, and geology, each in charge of a head curator and each composed of several divisions, anthropology having 8, biology 9, and geology 3. There are also 17 minor divisions, known as sections.

The scientific staff at the close of the year consisted of 3 head curators, 17 curators, 13 assistant curators, 15 custodians, 11 aids, 4 associates, and 1 collaborator, a total of 64 persons, but of these only 33 were under pay from the Museum, the remainder, nearly one-half of the scientific personnel, serving as volunteers or in an honorary capacity.

The executive office continued in the immediate charge of the Executive Curator, Dr. Frederick W. True, the Assistant Secretary exercising only a general supervision over the work, under the direction of the Secretary, who is the keeper *ex officio* of the Museum.

But few changes occurred in connection with the scientific staff. In the death of Mr. Frank Hamilton Cushing on April 10, 1900, the Museum, as well as the Bureau of Ethnology, lost one of its most active and distinguished workers, whose services with the Institution began nearly a quarter of a century ago. Medical Director James M. Flint, U. S. N., under whose charge the Division of Materia Medica was established in 1881, and who has been its Honorary Curator under detail by the Secretary of the Navy for three separate periods, aggregating about thirteen years, was placed on the retired list of the Navy in February, 1900. Proposing to continue his residence in Washington, however, Dr. Flint has volunteered his further services in the same capacity, and they have been gladly accepted. Mr. W. R. Maxon was appointed an aid in the Division of Plants in November, 1899.

Buildings.—The collections, laboratories, and offices are mainly provided for in the Museum and Smithsonian buildings, but the workshops are now housed in separate structures, two on the Smithsonian grounds and three in rented quarters south of B street S.W. A large amount of material still remains in storage in the large sheds on Ninth street and on Armory Square because of the lack of accommodations.

The need for additional quarters, which was long ago evident, has now become so urgent that unless relief is soon obtained it will be difficult to properly administer the affairs of the Museum or to fulfill its most important function as the custodian of all material objects resulting from Government explorations. Under the conditions as they now exist, some of the most valuable of the collections have to be kept in insecure buildings in the shipping cases in which they were received; they can not be arranged, classified, and made available to investigators as the law provides; the exhibition halls are overcrowded, preventing that enlargement in the display series which the public is led to expect; and the laboratory accommodations are greatly cramped, besides being in most cases very poorly adapted to their purpose.

The only noteworthy building alterations during the year were the substitution of a terrazzo pavement for wood in two of the halls and the flooring over one of the ranges, so as to obtain a second-story room for laboratory use by the Divisions of Mammals and Plants. The furniture acquired consisted of 40 exhibition cases and 250 storage cases, many of these being for the new galleries built during the preceding year.

Collections.—The increase in the collections has amounted to 206,617 specimens, bringing the total number now in the Museum up to 4,819,836. The additions, comprised in 1,467 different lots or accessions, represent the results of Government and other explorations, gifts, exchanges, purchases, and deposits.

The acquisitions by the Department of Anthropology have been especially numerous and important. Admiral Dewey has presented two antique brass cannon from the Spanish armament captured at Manila, and among other historical contributions have been the following: Many objects relating to the Spanish-American war, including uniforms, small arms, and cannon, from the Navy Department; military and personal relics of the Ord family, from Lieut. James T. Ord, U. S. A.; personal relics of Gen. Thomas Sword, from Miss E. H. Cotheal; a collection of cuttings from 33 flags of historic interest, from the Library of Congress; a series of autograph letters of men prominent in the civil war, from Mrs. L. O. Mason, and additions to the deposits of the Society of Colonial Dames and the Daughters of the American Revolution.

During the cruise of the U. S. Fish Commission steamer *Albatross* among the islands of the South Pacific Ocean, Mr. C. H. Townsend and Mr. H. F. Moore kindly gave attention on behalf of the Museum to the utensils and costumes of the natives, of which they secured a large collection. Many relics of the ancient peoples of Cuba and Jamaica were obtained by Maj. J. W. Powell and Mr. W. H. Holmes during a visit to those islands, and Dr. Walter Hough brought back from Mexico an interesting ethno-botanical collection, including many plants used in the native arts, ancient and modern, specimens of native handiwork, and a series of photographs.

The Hon. Perry M. de Leon, United States consul-general at Guayaquil, presented two ancient stone chairs from Ecuador, which, with other chairs surrounding a large stone table, were found in what appeared to be an ancient council chamber, brought to light about thirty years ago by the action of a freshet. A mummy from the valley of Cuzco, Peru, was contributed by Dr. C. H. Russell, U. S. N., of the U. S. S. *Newark*, and a collection of weapons of Australian aborigines, by the Hon. F. W. Goding, United States consul at Newcastle, New South Wales.

The Bureau of Ethnology has transmitted a collection of Indian skulls and other ethnological material obtained by Prof. J. B. Hatcher in Tierra del Fuego, Patagonia; a series of copper implements from Houghton County, Michigan; many stone implements from the West Indies, and a collection of baskets of the Washoe Indians. A collection of stone implements was deposited by Dr. Roland Steiner, of Grovetown, Georgia, and a collection of vases by the Grueby-Faience Company, of Boston, Massachusetts.

The following were obtained by purchase: A large series of objects illustrating the arts of the peoples of the Congo Valley of Africa, from the Rev. Samuel Phillips Verner, and a collection of ethnological specimens from the tribes of Angola, Africa, from the Rev. W. P. Dodson.

In the Department of Biology practically every branch has received additions of greater or less value. Dr. W. L. Abbott, whose explorations have enriched the Museum for many years, presented a large and important collection of zoological and ethnological material from the Malay Archipelago and other eastern localities, including Trong, Lower Siam, and Singapore, the zoological specimens comprising mammals, birds, batrachians, insects, and other groups of invertebrates.

From the Harriman Alaskan Expedition of 1899 the Museum has received the collections made in three groups, as follows: The birds by Mr. Robert Ridgway, the mollusks by Dr. William H. Dall, and the insects by Mr. Trevor Kincaid, of Seattle. The collection of insects is supposed to be the most complete one for Alaska that has yet been obtained, and was presented to the Museum by Mr. Harriman.

Extensive additions have been made to the collection of bats from Trinidad, Barbados, Cuba, and the Philippine Islands by Mr. E. T. Giers, Mr. P. Donough, Lieut. J. W. Daniel, jr., and Mr. L. M. McCormick. A skeleton of the recently discovered marsupial mole, *Notoryctes*, was received from University College, Dundee; an African rhinoceros was presented by the Forepaugh & Sells Brothers Menagerie, and many European mammals were acquired by purchase.

The Division of Birds has received the Goodfellow collection of humming birds, comprising about 1,200 specimens; 300 specimens of the birds of the United States of Colombia, from Mr. Outram Bangs; 500 specimens of Hawaiian birds, from Mr. H. W. Henshaw; a specimen of the Cuban Macaw (*Ara tricolor*), now believed to be extinct, from Maj. W. A. Glassford, U. S. A., and a skeleton of the rare Harris's Cormorant, from Leland Stanford Junior University.

Of fishes Dr. David S. Jordan has contributed a collection from Japan, including the types of 14 new species; the Museo Civico of Milan, Italy, a collection from the Red Sea and the Mediterranean; and the U. S. Fish Commission, specimens from Japan, Alaska, Hawaii, and California.

Many additions have been made to the Division of Insects, some of the most noteworthy being the following: The very important collection of spiders brought together by the late George Marx, containing several thousand specimens, among which were many types and cotypes; a large collection of Coleoptera from the late Hugo Soltau, of Louisville, Kentucky; many types and cotypes of species described by Prof. T. D. A. Cockerell, received from the New Mexico Agricultural Experiment Station; a series of insects collected in Porto Rico by Mr. August Busck, from the Department of Agriculture, and collections of Mexican Hymenoptera and South American Lepidoptera, obtained by purchase. Mr. E. A. Schwarz has continued to make important additions to the Hubbard and Schwarz collection of Coleoptera, presented to the Museum in 1898.

The Division of Mollusks has been enriched by collections made in Samoa by Sir Charles Eliot, the British representative on the Samoan Commission, and in Alaska and Hawaii by Dr. William H. Dall and others; by a series of South Australian shells received from Mr. Walter B. Reed, of Adelaide, and by a valuable lot of land shells from the Galapagos Islands, presented by the Leland Stanford Junior University. Through the addition last mentioned the National Museum is supposed to have acquired the most complete representation of Galapagos land shells now existing.

The more important acquisitions among the other groups of marine invertebrates have been as follows: From Dr. J. C. Branner, the crustaceans collected on the Brazilian coast by the Agassiz-Branner expedition of 1899; from Mr. H. W. Henshaw, Hawaiian crustaceans; from the U. S. Fish Commission, crustaceans and corals from Porto Rico; from the Biological Survey of the Department of Agriculture, crustaceans from Texas and Mexico; from Dr. C. H. Eigenmann, cotypes of an isopod crustacean from Izels Cave, Texas; from Dr. C. A. Kofoid, cotypes of a new genus of Volvocidæ; from Rev. George W. Taylor, of Nanaimo, British Columbia, cotypes of two species of British Columbia sponges.

The Herbarium is constantly in receipt of material from all parts of the world. Its most important addition last year was the private collection of plants belonging to Dr. Charles Mohr, of Mobile, Alabama, which he has generously presented to the Institution. This contribution, comprising upward of 3,000 specimens from the Southern States, is of especial value, as this region has heretofore been poorly represented in the National Museum. Mrs. Marie de Chalmot, of Holcomb Rock, Virginia, has donated 3,000 specimens of European and American plants, and Mr. A. H.

Curtiss, of Jacksonville, Florida, 1,100 specimens from the United States. Dr. J. N. Rose made a large collection of plants on his expedition to Mexico during the early part of the year, as mentioned elsewhere. The Department of Agriculture has transmitted 2,500 plants collected in Alaska by Mr. F. V. Coville and Mr. T. H. Kearney; 807 plants collected in the State of Washington by Mr. Kirk Whitead, and 2,300 plants collected in Virginia and North Carolina by Mr. T. H. Kearney. Four hundred and thirteen plants from Oregon have been received from the U. S. Geological Survey.

The principal addition to the Department of Geology was the extensive and unique collection of vertebrate fossils made for the U. S. Geological Survey by, or under the direction of, the late Prof. O. C. Marsh, and which was in the possession of the latter at Yale University at the time of his death, in 1899. A part of this collection, comprising two carloads, had been transferred to the Museum several years before. The remainder, filling 600 boxes and requiring 5 cars for its transportation, was received during the past year. This collection is the most important of its kind ever brought together, being exceedingly rich in large Dinosaurs, especially of the genera *Triceratops* and *Stegosaurus*. Of *Titanotherium* there are nearly 50 complete skulls. Forty or more species of Dinosaurs and of Jurassic, Cretaceous, and Tertiary mammals are represented by type specimens.

A nearly complete femur of a large Dinosaur, a fine specimen of the fossil gar (*Lepidosteus atrox*), a series of Mesozoic invertebrate fossils, and many lithological specimens were obtained in Wyoming by Mr. Charles Schuchert, and an interesting series of cycads was collected in the same State by Prof. Lester F. Ward and Mr. Schuchert.

A fine skull of an *Elotherium* and another of a *Diceratherium* were obtained by purchase; a series of Jurassic fishes, recently described by Mr. C. R. Eastman, was transmitted by the Geological Survey, and a well-preserved specimen of fossil gar (*Lepidosteus simplex*) was secured through exchange from the Glen Island Museum, New York.

An important collection of Texas Jurassic invertebrate fossils, described by Prof. F. W. Cragin, was received from the Geological Survey; a large number of Lower Helderberg fossils from New York, containing several new species, were obtained from Mr. John M. Clarke, and many Guelph (Upper Silurian) fossils were acquired by purchase.

A series of specimens showing the twenty stages in development of the Cambrian trilobite (*Sao hirsuta*) was received in exchange from the National Museum at Prag, Bohemia, through Dr. Anton Fritsch, and a restoration by Prof. C. E. Beecher of the fossil Crustacean, *Stylonurus*, from Yale University.

Many fossil corals were presented by the Hon. Delos Arnold, Prof. J. C. Merriam, Mr. T. W. Vaughan, and Mr. J. A. Singley, and a specimen of the rare echinoid *Oligoporus nobilis* was donated by Mr. W. L. Woods.

Collections of Cambrian brachiopods, of Rocky Mountain, Ordovician, Silurian, and Devonian fossils, and of fossil plants from a number of localities, as well as about 2,000 rock specimens representing areas recently examined by the Survey, including the Little Belt Mountains, the Uvalde, Anthracite and Crested Butte, and Big Trees quadrangles, and the Silver Cliff and Rosita districts of Colorado, were transferred by the Geological Survey to the keeping of the Museum.

A meteorite weighing about 64 pounds, which fell at Allegan, Michigan, on July 10, 1899, was purchased, and other meteorites were secured by exchange from the following localities: Jerome, Gove County, Kansas; Bishopville, South Carolina; Indarka, Augustinowka, and Bischtube in Russia; Lissa, Bohemia, and Schönenberg in Bavaria.

A large number of specimens of volcanic material collected in Hawaii by Prof. C. H. Hitchcock, and a series of orbicular granites from Finland, Sweden, and Rhode Island were added to the collections.

Prof. C. U. Shepard, of Summerville, South Carolina, has deposited the private collection of minerals which had belonged to his father, containing about 5,000 specimens, some of which are very choice. This collection was accompanied by a number of books, pamphlets, and manuscript notes.

Three fine opals have been added to the gem collection, and three Japanese beryls have been cut from rough specimens belonging to the Museum.

Explorations.—Although having very limited means for field investigations, at least a few members of the scientific staff spend a month or more during every year in adding to the collections, making their trips independently or in connection with expeditions sent out by other Government bureaus or under private auspices. Much important material is obtained in this way.

Dr. F. W. True spent several weeks of the summer of 1899 at the station of the Cabot Steam Whaling Company, in Newfoundland, studying the finback and humpback whales, which are the objects of the fishery in that locality. Anthropological researches were carried on in Cuba and Jamaica during the spring of 1900 by Maj. J. W. Powell and Mr. W. H. Holmes. Extensive zoological and botanical collections were made in Cuba and Porto Rico for the Pan-American Exposition by Dr. Leonhard Stejneger, Dr. Charles W. Richmond, Mr. William Palmer, and Mr. J. H. Riley, of the Museum staff. The Philippine Islands were visited by Col. H. H. Hilder, of the Bureau of American Ethnology, in the interests of the same exposition.

The expedition to Mexico by Dr. J. N. Rose and Dr. Walter Hough, which started in the spring of 1899, as noted in the last report, continued during a part of the summer and was very successful. Its object was the collection of both botanical and ethno-botanical specimens. At the close of the year Mr. Marcus W. Lyon, jr., was in Venezuela, having been detailed to accompany Lieut. Wirt Robinson, U. S. A., for the purpose of making collections of the higher vertebrates.

During the summer of 1899 Mr. Charles Schuchert accompanied an expedition under the auspices of the Union Pacific Railroad Company to the fossil beds of Wyoming, and he was also associated with Prof. Lester F. Ward in an examination of the region in Wyoming where fossil cycads abound.

On the Harriman expedition to Alaska, which was absent during June and July, 1899, the National Museum was represented by Dr. William H. Dall, Mr. Robert Ridgway, Dr. C. Hart Merriam, and Mr. F. V. Coville. Before returning to Washington Dr. Dall visited Hawaii for the purpose of studying its molluscan fauna.

The Government explorations which contribute most constantly and most extensively to the Museum are those conducted by the Geological Survey, the Fish Commission, and the scientific bureaus of the Department of Agriculture, in all of which there was much activity during the past year. The cruise of the Fish Commission steamer *Albatross* to the South Pacific Ocean offered an opportunity for securing ethnological objects from many interesting islands, and, through the courtesy of the Commissioner, two of the naturalists attached to the expedition, Mr. C. H. Townsend and Mr. H. F. Moore, were authorized to collect in this field.

Exchanges.—The exchange of duplicate specimens as a means of acquiring new material for its collections, authorized by the fundamental act establishing the Institution, has been carried on from the beginning and with much profit. The exchange may have reference to any number of specimens from one upward, and may be conducted with an individual, a museum of natural history, or any other character of establishment, provided, only, that a proper equivalent be sent in return. The domestic exchanges were many during the past year, though none was of large extent. The parties to exchanges from abroad were as follows: Great Britain—the British Museum of Natural History at London, the Royal Botanical Gardens at Kew, University College at Dundee, the Horniman Museum at London, Mr. G. E. Mason, of Fulham, and Mr. E. Lovett, of Croydon; France—the Museum of Natural History at Paris, and Mr. Jean Miguel, of Barrubio, Hérault; Germany—the Royal Zoological

Museum at Dresden, the Royal Botanical Museum at Berlin, and the Geological-Paleontological Institute at Munich; Bohemia—the National Museum at Prag, and Dr. K. Urba, of the same city; Italy—the museums of Natural History at Milan and Genoa, and Dr. Paolo Magretti, of Milan; Switzerland—Mr. Paul Narbel, of Cour Lausanne; Belgium—Baron R. de Vrière, of Phem, Zedelghem; Denmark—Dr. E. Warming, of the University of Copenhagen; Sweden—Prof. A. M. Fries, of Upsala; Russia—M. Melnikof, of St. Petersburg; India—the Indian Museum and the Royal Botanical Garden at Calcutta; South Africa—the Botanical Gardens at Durban, Natal; New Zealand—Canterbury Museum at Christchurch and the Public Museum at Wanganui; Australia—Mr. F. H. McK. Grant, at Melbourne, Victoria; Canada—Mr. Eugene Coubeaux, of Prince Albert, Saskatchewan; Mexico—the National Museum in the City of Mexico; Brazil—the Museo Paulista at São Paulo.

Installation.—Very considerable progress has been made in the work of installation, which comprises, besides the placing of specimens on exhibition, the arrangement of the reserve or study series and the packing away in storage of such material as can not be provided for in the overcrowded Museum and Smithsonian buildings. There is now on hand so large an amount of this material as to entirely fill a number of outside storehouses, and the quantity is being constantly increased. During the year it was thoroughly overhauled, the packing cases were relabeled as to their contents and sytematically arranged, and a complete catalogue was prepared to facilitate the finding of collections as desired. Among these stores are hidden away many thousands of valuable and interesting specimens, liable at any time to destruction by fire and pests—a silent but forcible reminder of the necessity for a new Museum building.

That part of the installation which interests the general public receives naturally the greatest amount of attention and involves by far the greatest expenditure of money. The exhibition cases must present a finished and artistic appearance; the collections, selected with due reference to the instruction of the visitor, must be suitably prepared and tastefully mounted, and each specimen, each grouping of specimens, and each case must have a label, tersely worded and easily decipherable. The reorganization of the exhibition halls is rapidly progressing. Some are being newly fitted up, while in others there is simply such a rearrangement, more or less extensive, as may be deemed necessary or as the circumstances permit. The lack of means to provide sufficient cases of a suitable character, however, interposes a serious difficulty in carrying on this work. A large proportion of the cases now in use are of antiquated pattern, and not adapted to modern methods of installation. Very many have been defaced or worn-out in connection with the different expositions, and until these can be replaced there must be much incongruity in the appearance of the exhibition halls.

Among the things accomplished in this direction by the Department of Anthropology has been the arrangement of the ceramic collection in a handsome, new, ebonized case, which extends around the entire gallery of the Northeast Court, producing one of the most attractive features in the Museum. The extensive basketry collection and the ethnological exhibits illustrative of Latin America have been installed in the corresponding gallery of the Northwest Court. The exhibits in the West North Range, which contains the Indian groups and the Catlin paintings, have been as nearly completed as is now possible, and many additions and improvements have been made in connection with the exhibits of American History, the Graphic Arts, Land Transportation, and Materia Medica. No changes have been made in the large hall so long occupied by the Division of Prehistoric Archæology, nor does any rearrangement there seem advisable until means shall be provided for a thorough renovation of the room, which is now in every respect quite unpresentable.

For the Department of Biology one large wall-case has been built along the east side of the South Hall, to receive the specimens of North American carnivores, and the installation in this hall has been otherwise much improved. The Southeast Range has been cleared of storage, and entirely assigned to the exhibition of reptiles and fishes, of which a partial display is now in place. The rearrangement of the bird collection has been nearly completed, and a system of lighting the central dark cases by means of electric lamps has been devised.

The condition of both the exhibition and reserve collections in the Department of Geology has been greatly improved, and, except as to labeling, many parts of the display series are now in a practically finished state. The two galleries in the southern ranges have been fitted up as storerooms and laboratories for the Divisions of Paleobotany and Vertebrate Paleontology, the collections of which have been transferred to the racks and drawers provided for the purpose. Much of the activity of the Department of Geology has been directed toward unpacking and arranging the Marsh Collection of vertebrate fossils, to which reference is made elsewhere.

Public benefits.—While the principal function of the Museum is to care for and classify the Government collections, it is best known to the public through its educational features and as a place where information may be sought on many scientific topics. Being one of the chief points of interest at the national capital, it is visited by large numbers of persons from all parts of the country, the annual attendance during the past twenty years having averaged about 220,000, though in years of Presidential inauguration it has sometimes exceeded 300,000. During the past year the number recorded was above 225,000.

In the matter of supplying information the Museum is called upon from all parts of the country and to some extent from abroad. Specimens are sent to it for identification and analysis, and inquiries are received bearing upon every subject coming within its scope, as well as upon many with which it has no relation. Every communication is answered, and so far as possible the writer's wishes are complied with, though requests for chemical analyses can not be met, as the Museum is not equipped for work of that character. Over 700 lots of objects were received for examination during the year, while of letters asking information there was an average of not less than 100 weekly. As will be realized, the time of both the scientific and the clerical staff was heavily drawn upon in preparing the necessary replies.

A number of students have been given facilities and allowed the use of collections for carrying on researches at the Museum, and a large amount of material has been sent to specialists in different parts of the country and abroad for working up. While the latter has mainly been done under agreement to prepare reports for the use of the Museum, yet specimens are constantly being lent to institutions and individuals to aid in investigations conducted in their own behalf.

The distribution of duplicate specimens among educational establishments throughout the United States has come to be regarded as one of the important features in the work of the Museum. It can only be carried on, however, upon a very limited scale with the funds now available, as entire collections have first to be identified, and the expenditure of a relatively large amount of labor and material is required for assorting, labeling, and preparing the specimens for shipment. During the last year 39 sets of such duplicates, containing about 7,000 specimens in all, were sent out. The principal subjects represented were marine invertebrates, geology, and prehistoric archæology.

Pan-American Exposition.—The preparation of the exhibits for the Pan-American Exposition at Buffalo in 1901, as authorized by the Fifty-fifth Congress, was begun during the year under the immediate direction of Dr. F. W. True, who has been designated as the representative of the Smithsonian Institution and its bureaus on the Government Board of Management.

Publications.—Volume 21 of the Proceedings was issued early in the year, and 24 papers of Volume 22 have been printed and distributed in separate form. Volume 1 of the Annual Report for 1897 was received from the Government Printing Office in

December. The second volume of this Report, still in course of printing, will contain a biographical account of Dr. George Brown Goode, the late Assistant Secretary of the Smithsonian Institution, in charge of the National Museum, and reprints of several of his most important papers on museums and on the history of scientific progress in the United States. It is expected that the Report for 1898 will be ready for distribution early in the coming fiscal year. The appendix to this Report will consist of only one paper—a monographic treatise on the Crocodilians, Lizards, and Snakes of North America, by the late Prof. Edward Drinker Cope. Part 4 of Bulletin No. 47, entitled "The Fishes of North and Middle America," by Dr. David Starr Jordan and Dr. Barton W. Evermann, was issued just before the close of the year. This volume, consisting of 392 plates, with their explanations and a general table of contents, completes one of the most important works thus far published by the Museum. Three additional pamphlets containing instructions to collectors, etc., were issued during the year as parts M, N, and O, of Bulletin 39. The titles of these are: "The methods employed at the Naples Zoological Station for the preservation of marine animals," by Dr. Salvatore Lo Bianco (translated by E. O. Hovey, of the American Museum of Natural History); "Directions for preparing study specimens of small mammals," by Gerrit S. Miller, jr., and "Directions for collecting and rearing dragon flies, stone flies, and May flies," by James G. Needham.

Library.—Three hundred and thirty-seven books, 728 pamphlets, and 4,298 parts of periodicals have been added to the library, which now contains over 15,000 bound volumes and 27,000 unbound papers.

Respectfully submitted.

RICHARD RATHBUN,
Assistant Secretary.

Mr. S. P. LANGLEY,
Secretary Smithsonian Institution.
AUGUST 1, 1900.

Appendix II.

REPORT OF THE DIRECTOR OF THE BUREAU OF AMERICAN ETHNOLOGY FOR THE YEAR ENDING JUNE 30, 1900.

Sir: I have the honor to tender the following report of operations conducted by the Bureau of American Ethnology during the year ending June 30, 1900, in accordance with the act of Congress making provision "for continuing researches relating to the American Indians under the direction of the Smithsonian Institution," approved March 3, 1899.

The work of the year has been carried forward in accordance with a formal plan of operations submitted on May 13, 1899, and approved by the Secretary under date of June 16, 1899.

The field operations of the regular corps have extended into Arizona, California, Cuba, Indian Territory, Jamaica, Maine, Minnesota, New Mexico, New York, Nova Scotia, Oklahoma, Ontario, and Wisconsin; while operations have been conducted by special agents in Alaska, Argentina, and Porto Rico. The office work has comprised the collection and preparation of material from most of the States and Territories, as well as from various other parts of the Western Hemisphere.

As during previous years, the researches have been carried forward in accordance with a scientific system developed largely in this Bureau. This system is outlined in the classification adopted in previous reports and continued in the present one.

FIELD RESEARCH AND EXPLORATION.

The Director, aided by Mr. Frank Hamilton Cushing, spent the earlier months of the fiscal year in an investigation of the middens and tumuli representing the work of the aborigines in northeastern United States, especially in Maine. A considerable number of both classes of accumulations were excavated, with instructive results. Among the relics brought to light were many of customary types, together with a smaller number of much significance in that they represent early stages of acculturation through contact with Caucasian pioneers; and in addition to the aboriginal and accultural artifacts, the explorers were rewarded by finding the remains of a metallic armor, of European make, in such associations as to throw light on the beginning of warfare between red men and white.

Later in the year the Director, accompanied by Prof. W. H. Holmes, of the United States National Museum, repaired to Cuba and Jamaica for the purpose of tracing lines of cultural migration between the great continents of the Western Hemisphere. The researches of the last two decades have shown clearly that the customs of the aborigines in what is now southeastern United States were affected by extraneous motives and devices; the phenomena have suggested importation of objects and ideas belonging to what is commonly styled "Caribbean art" from South America by way of the Antilles; and it was thought desirable to seize the opportunity offered by recent political changes for special studies in the Antillean islands. Although the trip was a reconnaissance merely, it yielded useful data on which to base further researches, including a small collection for the Museum.

A noteworthy trip was made early in the fiscal year by Mr. F. W. Hodge, with a party of volunteer assistants comprising Dr. Elliott Coues, of Washington, Dr. George Parker Winship, of Providence, and Mr. A. C. Vroman, of Pasadena. The journey was so planned as to touch the less known pueblos of the plateau country and valleys of New Mexico and Arizona and to obtain data relating to social organization, migrations, and customs, as well as typical photographs of individuals, habitations, etc. All of the existing pueblos of New Mexico were visited and many of the ruins. The trip yielded a large body of data for incorporation in the reports and especially in the Cyclopedia of Native Tribes.

About the middle of September Dr. J. Walter Fewkes proceeded to New Mexico for the purpose of completing his investigation of the mythology and ceremonies of the Hopi Indians, his trip being so timed as to permit observation of the autumn and winter ceremonies not previously observed by ethnologic students. He remained in the pueblo throughout the winter, and his studies proved eminently fruitful. Toward the end of March he repaired to Arizona for the purpose of locating aboriginal ruins near Rio Colorado Chiquito, concerning which vague rumors were afloat; and this work, also, was quite successful, as noted in another paragraph.

During the early autumn Dr. Albert S. Gatschet visited several groups of survivors of Algonquian tribes on Cape Breton Island for the purpose of extending the studies of the previous year in New Brunswick; he succeeded in obtaining considerable linguistic material, in addition to other data pertaining to the northeasternmost representatives of that great Algonquian-speaking people neighboring the Eskimo on their north and extending thence southward more than halfway across the present territory of the United States.

Early in the winter Mr. J. N. B. Hewitt revisited the remnants of several Iroquoian tribes in New York and Ontario and continued the collection and comparison of the tribal traditions. Finding the conditions favorable for recording some of the more noteworthy traditions, he spent several weeks in an Indian village near Hamilton, Ontario, returning to the office in April.

Toward the end of the calendar year Mr. J. B. Hatcher, who had been operating in Patagonia and Terra del Fuego as a special agent of the Bureau, returned to the country with a considerable collection for the Museum, as well as a large number of photographs illustrating the physical characteristics, costumery, habitations, and occupations of the Tehuelche and Yahgan tribes. He also brought in an extended vocabulary collected among the natives of the former tribe and useful notes relating to the social organization and other characteristics of the two tribes.

Toward the end of the fiscal year Miss Alice C. Fletcher was commissioned as a special agent to visit Indian Territory and Oklahoma for the purpose of obtaining certain esoteric rituals of the Pawnee tribe. Her work was notably successful, as is indicated in other paragraphs.

Dr. Willis E. Everett remained in Alaska throughout the fiscal year, pursuing his vocation as a mining engineer, but incidentally collecting, for the use of the Bureau, linguistic and other data pertaining to the native tribes.

About the beginning of the fiscal year Dr. Robert Stein, formerly of the United States Geological Survey, accompanied a Peary expedition northward as far as Elsmereland, where he planned to spend the winter in geographic and related researches. He carried instructions from the Bureau for such archæologic and ethnologic observations as he might be able to make, together with photographic apparatus and materials needed in the work. Elsmereland is not known to be now inhabited, nor to have been inhabited in the past, by the aborigines, but the situation of the island is such as to indicate that it was probably occupied at least temporarily by Eskimauan tribes in some of the migrations attested by their wide distribution; hence it is thought probable that archæologic work on the island may throw light on the early history of this widely dispersed orarian people. A brief report of progress was received after the close of the fiscal year.

During the autumn Mr. Robert T. Hill, of the United States Geological Survey, visited Porto Rico in the interests of that Bureau and of the Department of Agriculture; and the opportunity was seized to arrange for obtaining through his cooperation such photographs and other data of ethnologic character as he might be able to discover in connection with his other duties. The arrangement yielded material of value.

Office Research.

WORK IN ESTHETOLOGY.

In the course of a reconnoissance of the Greater Antilles, the Director and Professor Holmes enjoyed moderate opportunities for observing (chiefly in local collections) artifacts of the class commonly regarded as displaying traces of Caribbean influence; and while neither time nor opportunity permitted exhaustive study, a few interesting generalizations were made. One of these relates to the relative abundance of æsthetic and industrial motives among those artifacts displaying traces of a Southern influence. On comparing the objects and special features in connection with those from Florida and other portions of southern United States, it was noted that the presumably imported or accultural features are predominantly esthetic, and only subordinately of technical or industrial character—i. e., it would appear from the collections that esthetic motives travel more freely, or are interchanged more readily, than purely utilitarian motives among primitive peoples. The relation is of course complicated by the relative abundance of fiducial or other sophic motives, which often blend with both æsthetic and industrial motives in puzzling fashion; but even after these motives are weighed or eliminated, the general relation remains unchanged. The generalization promises to be of service as a guide in the study of that affiliation of tribes, or integration of peoples, which complicates every ethnologic problem. The inquiries were greatly facilitated by Professor Holmes's artistic training and his extended familiarity with both the esthetic and the industrial motives of aboriginal artifacts; nor could the generalization have been made without the aid of Mr. Cushing, and the opportunity of examining his remarkable collection of artifacts of wood and shell from the muck beds of western Florida, of which a considerable part is now in the National Museum. The details of the work are reserved for later reports.

Throughout the fiscal year Mr. W J McGee was occupied primarily with administrative duties as Ethnologist in Charge in the office, but partly in the preparation of reports on field researches of previous years. One of his subjects of study was the esthetic status of the Seri Indians of Tiburon Island and adjacent territory. The tribe is notably primitive in several respects, as indicated in previous reports, and this primitive character is well displayed in their meager esthetic. One of the conspicuous customs of the tribe is that of face painting, the paint being applied uniformly in definite patterns, of which nearly a dozen were observed. The custom is practically limited to the women, though male children are sometimes painted with their mothers' devices. On inquiry into the uses and purposes of the designs it was found that each pertains to and denotes a matronymic group or clan, and that the more prominent designs, at least, are symbols of zoic tutelaries—e. g., Turtle, Pelican, etc. It thus appears that the painted devices are primarily symbolic rather than decorative, though comparison of the devices used by different members of the same clan or by the same female at different times, indicates that the sematic function does not stand in the way of minor modification or embellishment of the device through the exercise of a personal feeling for decoration. The investigation is of interest in that it establishes the symbolic basis of æsthetic concepts along a new line, and it is of even deeper interest in that it seems to reveal nascent notions of decoration, and thus aids to define the beginning of purely artistic activities. The symbolic devices themselves are of much significance as indices to the social organization on the one hand, and to the prevailing belief of the tribe on the other hand. The restriction of the painted symbols to the females and the especially conspicuous use of them by matrons betoken the strength and exclusiveness of that sense of maternal descent which is normal to the lowest stage of culture; the devices are at once blood-signs, definite as the face-marks of gregarious animals, and clan-standards, significant as tartan or pibroch; and the confinement of their display to the recognized blood-carriers of the clan attests, perhaps more clearly than any other phenomena thus far noted, the strength of that semi-instinctive feeling expressed in maternal organization. In like manner, the representation of local tutelaries in the painted devices attests the intensity and dominance of that zootheistic faith which seems to be normal to the lowest stage of intellectual development. The details of the investigation are incorporated in a memoir appended to an earlier report.

In the course of his work among the Hopi Indians, Dr. Fewkes succeeded in defining certain steps in the development of the drama. The ceremonies of the folk, like those of other primitive peoples, are primarily fiducial, and involve representation, or even personation, of the deified potencies forming the tribal pantheon. The motive of one of the dramatic—or rather dramaturgic—pieces is the growth of corn; and the mise en scène comprises realistic representations of both the maleficent and the beneficent agencies connected with the making of the crop and the development of the plant in general. The performance is designed primarily to invoke the favor of the mysteries by appropriate symbols of both being and action, but an ancillary, or perhaps coordinate, design of this ceremony is the edification (combining instruction and diversion) of the tribe at large; accordingly a portion of the interior is set apart as a stage, while the greater portion is reserved as an auditorium. Both the mystical and the human powers are represented or personified by actors, who, with their properties, occupy the stage; and since that part of the mechanism connected with the portrayal of the mysteries is esoteric, a screen is provided to conceal it and give an air of realism to the performance. The screen is painted with appropriate symbols tending to heighten the illusion to the childlike minds of the audience, and it is perforated to permit the passage of masked effigies representing the mystical potencies, which are operated by shamans hidden behind the screen, something after the fashion of marionettes. The front of the stage is occupied by a symbolized field of corn; it is the rôle of the symbolized potencies representing storm and drought to emerge from their respective apertures in the screen and destroy the symbolic cornfield; but they are opposed, in part by musical and other incanations of a group of shamans occupying one side of the stage, and in part by human actors who wrestle with and finally overcome the evil marionettes. The entire dramatization stands on a higher plane than that prevalent among most of the tribes of the territory of the United States, though lower than that reached among the Nahuatlan and Mayan peoples and reveals various connecting links between primitive dramaturgy and theatrical representation proper. A specially significant feature of the performance is the rôle assigned to human actors in boldly defying, and eventually overcoming, the powers of darkness and evil; for this æsthetic feature reflects a noteworthy aspect of industrial development. Dr. Fewkes's detailed descriptions, with the attendant photographs and drawings, are in preparation for an early report.

WORK IN TECHNOLOGY.

As indicated in earlier reports, the researches of the last decade have shown that the esthetic motives of primitive peoples arise in symbolism; and, as noted in one or two recent reports on the work, various indications have been found that industrial motives similarly arise in symbolism connected with zootheistic faith. The suggestive phase of industrial development is that in which teeth, horns, claws, mandibles, and other animal organs are used as implements or weapons in a manner imitating more or less closely the natural functions of the organisms. In completing his studies of Seri technic during the year, Mr. W J McGee has discovered definite survivals of this stage of industrial development. The favorite Seri awl is the mandible of a bird, and even when the material is hard wood the implement is shaped in imitation of the natural organ; the war shield is a turtle-shell or pelican pelt; similarly the arrows and turtle harpoons of the tribe are fitted with a foreshaft usually of hard wood, though there are linguistic and other indications that the use of wood is a vestige of a former use of teeth, probably of the local sea lion while many of the manual operations are evidently imitative of normal movements of local animals, most of which hold place in the Seri pantheon. These features of the Seri technic throw light on the use of zoic motives in the decoration of primitive weapons, and hence permit the solution of some of the most puzzling problems of American archeology; at the same time they serve to define a stage in industrial development in a manner which appears to be applicable to all primitive peoples. In general, the stage would seem to be antecedent to that defined by the chance-dominated use of stone, which has already been characterized as protolithic; it corresponds with the stage provisionally outlined by Cushing as prelithic; but, taking due account of the materials, processes, and motives characteristic of the stage, it may be distinguished as hylozoic, or perhaps better as zoomimic. Accordingly the earlier stages of industrial development mav be defined as (1) zoomimic, in which the predominant implements are beast organs, used largely in mimicry of animal movements; (2) protolithic, in which the prevailing implements are stones selected at random and used in ways determined by mechanical chance; and (3) technolithic, in which the prevailing implements are of stone shaped by preconceived designs and used in accordance with the teachings of mechanical experience. This classification of the industries is elaborated in an earlier report, the material for which was revised during the year.

In continuing the preparation of his memoir on the contents of the Flórida shell mounds and muck beds, Mr. Cushing brought out many new examples of that ideative association which forms the basis of zoomimic industry. Several of these examples were found in the muck-preserved implements and weapons of wood from Florida; others were found in various museums in the form of artifacts of stone, and even of metal, shaped in imitation of animals, or furnished with symbols of animals and animal organs; still others were found in the hieroglyphics and hieratic codices of Mexico and Yucatan. The assemblage of objects seems clearly to indicate that while the zoomimic motive was the primary one and stood nearly alone at and long after its inception, it was not completely displaced by the protolithic or even by the technolithic motives of higher stages, but persisted in connection with these quite up to the time of Caucasian invasion—indeed, it would appear that the zoomimic motive in handicraft was the correlative and concomitant of that zootheism out of which none of the tribes had completely risen up to the time of the discovery.

In the course of his reconnaissance of the inhabited and ruined pueblos in New Mexico and Arizona, Mr. F. W. Hodge, with his companions, brought to light a number of notable examples of stone work. Two types are especially instructive. The first of these is represented by the ruins in Cebollita Valley. The stones used in the walls were cleft with great regularity and laid, after carefully facing by pecking, in such manner as to produce a practically smooth surface, with corners squared almost as neatly as those of a well-laid brick structure. The second type, also represented by ruins in the Cebollita Valley, is similar, save that the corners were rounded apparently on a uniform radius, while the stones were dressed in such manner as to conform to the curve about as closely as does metal-wrought masonry. The perfection of the stone work of both types suggests Caucasian skill; but the indications of great antiquity, coupled with the absence of binding mortar, and especially the laying of the stones in such manner as to reveal ignorance of the principle of breaking joints, prove that the work was primitive.

In his reconnaissance of the ruins of Rio Colorado Chiquito, Dr. Fewkes reexamined critically the ancient structure discovered by Sitgreaves in 1851, which is of much interest as one of the earliest known ruins of the pueblo country. His observations on the subject are of interest, partly in that they afford a basis for estimating the duration of such ruins when protected from vandalism either by inaccessibility, as in this case, or by such legislative or executive action as is frequently contemplated by governmental authorities. The detailed measurements and comparisons will be incorporated in a later report. During the same trip Dr. Fewkes discovered a number of additional ruins including those of cavate dwellings located in the softer layers of heterogeneous volcanic deposit. Some of his observations throw useful light on the methods of excavating such deposits employed by the aborigines, as well as on their general modes of life.

During the autumn it was ascertained that Dr. A. E. Jenks, of the University of Wisconsin, was engaged in a study of the wild-rice industry of the aborigines, and it was thought well to take advantage of the opportunity to systemize and place on permanent record the considerable body of material brought together through his researches. Accordingly provision was made to have Dr. Jenks visit various localities in Wisconsin and Minnesota in which the wild-rice industry is still carried forward by the Indians; and provision was also made for photographing the various operations connected with the harvesting, preserving, and cooking of the produce. The inquiry derives importance primarily from the large use of wild rice among the aboriginal tribes and incidentally from the possible utility of the product in enlightened agriculture. The world is indebted to the natives of the Western Hemisphere for several important commodities. Among these corn, i. e., maize, occupies the first place; others are the turkey, two or three varieties of beans, certain squashes, besides the remarkable paratriptic tobacco, whose use has spread throughout the world since the time of Raleigh; and there are indications that the wild rice (*Zizania*) of the region of glacial lakes may constitute a notable addition to the list. Led to the subject by the work of the Bureau, the Department of Agriculture has instituted inquiries concerning the extent of the wild rice area and concerning the possibilities of utilization of the resource. Dr. Jenks' memoir is incorporated in the Nineteenth Annual Report.

WORK IN SOCIOLOGY.

Except when occupied in field work, the Director continued the synthetic study of demotic activities, and during the year he completed the preliminary outline of the activities expressed in institutions. The science of institutions is commonly designated sociology, after Auguste Comte, Herbert Spencer, and other European writers; and though the term is sometimes loosely used it fairly meets the requirements of scientific exposition. The branch of knowledge which it is used to designate is one of the five coordinate sciences (esthetology, technology, sociology, philology, and sophiology) constituting demonomy, or the system of knowledge pertaining to the human activities. Viewed in its activital aspect, sociology combines several subordinate branches. The first of these is statistics (sometimes called demography), which deals with the units of social organization; the second is economics, which deals especially with the forces and values involved in, or controlled by, human organization. The third branch of sociology is civics, which may be defined as the science of methods in governmental action, or in the regulation of the conduct of associates—methods which have for their normal objects peace, equity, equality, liberty, and charity among the associates. The means of attaining these ends in primitive society have been ascertained almost wholly through the researches in American ethnology; they have been indicated in a brief outline of regimentation appended to an earlier report. The fourth branch of sociology may be noted as historics; it deals with the methods adopted for the maintenance and perpetuation of social organization. Coordinate with these branches is the science of ethics, which deals with the ideal bases and the practical objects of associate organization. The ethics of primitive life have been ascertained almost wholly through observation among the aborigines of America; the ethical relations existing among the tribesmen have been a revelation to students; and no line of ethnologic inquiry has yielded richer results than that pertaining to this subject. An outline of the definition of sociology has been printed for the use of students, and for the benefit of such suggestions as may be offered by other inquirers; and it is planned to expand the discussion and incorporate it in a later report.

The primary purpose of the trip by Mr. Hodge and his companions was to ascertain and record the details of social organization as now maintained among the pueblo tribes. As indicated in various publications of the Bureau, the aborigines of America belong in approximately equal proportions to two of the culture stages defined by social organization—i. e., (1) savagery, in which the institutions are based on consanguinity reckoned in the female line, and (2) barbarism, in which the institutions are founded on consanguinity reckoned in the male line. In some cases a transitional condition has been found, as, for example, among the Muskwaki Indians, who give a patronymic to the first-born child, but, in case of its death in infancy, revert to the matronymic system; sometimes, again, the basis of the organization is so well concealed as to be obscured, as among the Kiowa Indians (noted in the last report); or, again, the consanguinity may be practically concealed by the overplacement of some other factor, as among the California tribes, who regard language as the ostensibly dominant factor of their institutions (also noted in the last report); but the fortuitous relations may commonly be reduced without serious difficulty, and shown not to affect the general fact that the American aborigines belong to the culture stages of savagery and barbarism in about equal proportions, reckoned on the basis of population—though it is to be remembered that the tribes belonging to the higher stage are much the larger and fewer. Now a recent line of inquiry relates to the causes and conditions of the transition from the first great stage to the second. In the Old World the transition has been fairly correlated with the gradual passage from hunting to herding—there the initial phase of agriculture; but in the Western Hemisphere the characteristics of the native fauna were not such as to place herding in the van of agricultural development. Accordingly it has been thought desirable to trace the influence of harvesting and planting, when pursued for generations, on social organization; and the most favorable opportunity for such research was that afforded by the Pueblos. Morever, it seemed desirable to inquire into the rate of the transition, as indicated by records covering a considerable period; and for this purpose also the Pueblos seemed to be admirably adapted, partly since the customs of the people have been subjects of record for three and a half centuries, and partly because their arid habitat is so uninviting as to have practically repelled the invasion of revolutionary methods. It was by reason of his intimate acquaintance with the early records, and also in the hope that he might be able to discover unpublished manuscripts among the ancient archives of the missions, that Dr. Elliott Coues, compiler of the American Explorers' Series, was attached to the party. Although no noteworthy discoveries of manuscripts were made, a considerable body of data essential to the discussion of social organization in the pueblo region was obtained. Portions of the material are in preparation for prospective reports, while Mr. Hodge is incorporating the data relating to the clans and gentes of the Pueblo peoples in a Cyclopedia of Native Tribes.

During his stay among the Hopi, Dr. Fewkes' attention was directed to the interrelation between the tribesmen and certain feral creatures, notably eagles. The eagles are of much consequence to the folk, chiefly as a source of feathers, which are extensively used in ceremonies for symbolic representation, etc.; and it appears from the recent observations that particular clans claim and exercise a sort of collective ownership in certain families of eagles, perhaps homing in distant mountains; and that this right is commonly recognized by other clans, and even by neighboring tribes. Thus the relation affords a striking example of that condition of toleration between animals and men which normally precedes domestication, and forms the first step in zooculture, as has been set forth in preceding reports. These relations, together with the methods of capture, etc., will be described in a prospective paper.

WORK IN PHILOLOGY.

During the later months of the fiscal year the Director resumed the synthesis of the native American languages, and the comparison of these with other tongues, with the view of defining the principles of philology on a comprehensive basis. The task is one of magnitude; the records in the Bureau archives comprise more or less complete vocabularies and grammars of several hundred dialects representing the sixty or more linguistic stocks of North America; and the study necessarily extends not only over this material but over a considerable part of the published records of other languages, both primitive and advanced. Accordingly, while satisfactory progress was made in the work, definite announcement of results must be held for later reports.

In connection with the general linguistic researches it was deemed necessary to extend the classification of stocks southward over Mexico and Central America; and this extension was undertaken with the aid of Dr Cyrus Thomas, whose researches concerning the native codices of Mexico and Yucatan have familiarized him with the literature of these and neighboring regions, and to some extent with the aboriginal languages. Dr. Thomas devoted several months to the work; and about the close of the fiscal year he had completed a provisional classification and map of native linguistic stocks in Mexico and Central America, designed to supplement the classification and map of the American Indians north of Mexico published in the Seventh Annual Report. The material remains in the hands of the Director for use in general study and for revision for publication.

As noted above, Dr. Albert S. Gatschet visited Nova Scotia early in the fiscal year for the purpose of completing his collections of the northeasternmost Algonquian tongues—his work on Cape Breton Island was especially fruitful—and his collections will enable him to round out the comparative vocabulary of Algonquian dialects so far as the tribes of northeastern United States and contiguous territory are concerned. On returning to the office he resumed the extraction of lexic and grammatic material, and pushed forward the preparation of the comparative vocabulary, and in connection with the work he prepared synthetic characterizations of the principal elements of several typical dialects, including the Kataba of the Siouan stock.

Mr. J. N. B. Hewitt continued the preparation of his memoir on the comparative mythology of the Iroquoian tribes. On juxtaposing the principal cosmogonic myths of the several tribes, various indications of incompleteness were found; and it was chiefly for the purpose of verifying certain of the versions that he revisited Ontario, as has been already noted. He succeeded in obtaining a considerable body of new data, and after his return from the field he made good progress in the preparation of his memoir, which is designed for incorporation in an early report. Early in the fiscal year Mr. Hewitt made a notable comparison between the Seri language, as recorded recently by Mr. McGee (and as previously obtained from an expatriated Seri man at Hermosillo by M. Pinart, Commissioner Bartlett, and Señor Tenochio), with the Yuman, Piman, and other southwestern dialects recorded by various explorers. For a time the language of the Seri was supposed to be related to the tongues of the Yuman stock; but Mr. Hewitt's exhaustive study of the extensive body of material now preserved in the Bureau archives seems to demonstrate the absence of such relation, and to indicate that the language of the tribe represents a distinct stock. Accordingly the classification of Orozco y Berra and other Mexican scholars of the middle of the century is revived; and in conformity with the principles of nomenclature and classification announced in the Seventh Annual Report, the definition of the language, dialects, and tribes is as follows:

Stock.	*Dialects and tribes.*
Serian.	Seri (extant).
	Tepoka (recently extinct).
	Guayma (long extinct).
	Upanguayma (long extinct).

In the course of his stay in the Hopi Village, Dr. Fewkes was so fortunate as to discover a series of hieratic paintings, primarily representing the tribal pantheon, but connected incidentally with the tribal history. The paintings were executed by an aged shaman as a sort of personal record akin to the calendars, or winter-counts, which play so large, yet so obscure, a rôle in Indian life; and they would doubtless have been sacrificed on the death of the artist had not Dr. Fewkes discovered them and succeeded, after much difficulty, in securing them. The series comprises some four hundred representations, mostly on separate sheets; the pictures partake of the characteristics of the petroglyphs and calendaric inscriptions such as those described by the late Colonel Mallery; they also present suggestive similarities to the codices of more southerly regions. It is the design to incorporate the entire series, reproduced in facsimile, in an early report.

One of the best known contributions to American aboriginal linguistics is the Elliot Bible, published in the Natick language in 1685. This contribution was supplemented in a highly notable way during the present century through the labors of the late James Hammond Trumbull, who compiled from the Bible, with the aid of other sources of information at his command, a vocabulary of the Natick tongue. Unfortunately for students, this compilation was not published, but on the death of Dr. Trumbull, in 1897, it passed into the custody of the American Antiquarian Society, at Worcester, Massachusetts. Here it attracted the attention of scholars and publicists, including Dr. Edward Everett Hale; and it was proposed by Dr. Hale, with others, to offer the manuscript to the Bureau for publication. Among the scholars interested in this and cognate publications relating to the aborigines was the Hon. Ernest W. Roberts, Representative of the Seventh Massachusetts district in the Congress; and at his instance authority was granted for resuming the publication of bulletins by the Bureau. Accordingly, when Dr. Hale, early in 1900, brought the valuable manuscript of the Trumbull Dictionary to Washington it was assigned for publication as the first of the new series of bulletins. Before the close of the fiscal year the compositon was well under way, while Dr. Hale was engaged in the preparation of a historical introduction.

Another contribution of the first importance to knowledge of the aboriginal American languages is the vocabulary of the Maya tongue, compiled during the earlier decades of Spanish occupation and well known to scholars (though never printed) as the Diccionario de Motul. Two or three copies of the work are extant in manuscript; one of these passed into the possession of the late Dr. Carlos H. Berendt about the middle of the present century, and in the course of a lengthy stay in Yucatan he undertook to revise and complete the vocabulary and to bring it up to date by the introduction of all Maya terms in modern use. Dr. Berendt's additions nearly doubled the volume of the original manuscript, and greatly enhanced its value; unfortunately he died before his plan for publication was carried out. Before his death, however, he turned the manuscript over to the late Dr. Daniel G. Brinton, of Philadelphia, in order that it might be published in that ethnologist's Library of Aboriginal American Literature. Finding the work too extensive for his facilities, Dr. Brinton made a provisional arrangement, before his death, in July, 1899, to transfer the manuscript to the Bureau; and after his decease the arrangement was carried out by his legatees and executors, including the University of Pennsylvania, to which institution his valuable library was bequeathed. Both the original vocabulary and Dr. Berendt's supplement are in Maya-Spanish and Spanish-Maya; and, as a necessary preliminary to publication by the Bureau, a transcription was begun by Miss Jessie E. Thomas, assistant librarian, a student of the Maya language. Toward the close of the fiscal year Señor Andonaro Molina, of Merida, Yucatan, an eminent student of the Maya language, visited this country, and, learning of the proposal to publish the Diccionario de Motul, came to Washington to proffer his services in any further revision of the material that might seem desirable. His offer was gladly accepted and provision was made for supplying him with copies of the transcript of the vocabulary.

During the year Dr. Franz Boas made additional contributions of importance to the linguistic collections of the Bureau. He also completed a second volume of Chinook texts, which would have been sent to press before the close of the fiscal year except for his prospective absence in field work and consequent delay in proof revision. The matter will be incorporated in an early report or bulletin.

WORK IN SOPHIOLOGY.

In pursuing his investigation of the time-concept of Papago Indians as noted in the last report, Mr. McGee was led to a study of the relations existing between this notably altruistic tribe and their hard physical environment; and clear indications were found that with the degree of cultural development possessed by the Papago, the tendency of a severe environment is to develop altruism. At the same time it was noted that the neighboring Seri tribe, surrounded by an environment of similar characteristics in many respects, are notably egoistic and inimical toward contemporaries; and the striking differences led to further research concerning the interrelations between human groups and their physical surroundings—interrelations which may conveniently be styled adaptions. Now, when the study was extended to other tribes it became manifest that such adaptions may be arranged in serial order, and that when so arranged the Seri stand at the end of the series marking the most intimate interaction between mind and externals, while the Papago stand in the front rank of aboriginal tribes as graded by power of nature-conquest; and from this point it is easy to extend the scale into civilization and enlightenment, in which men control rather than submit to control by their physical surroundings. The serial arrangement of peoples in terms of relative capacity in nature-conquest can hardly be deemed new, though the special examples (particularly the notably primitive Seri) are peculiarly instructive; but the successive adaptions thus defined were found unexpectedly significant in measuring various degrees of interdependence between environment and thought, for it became evident in the light of specific examples that the habitual thought, like the habitual action of an isolated and primitive folk is a continuous and continuously integrated reflection of environment. On pursuing the relations it was found that the Seri, habitually submitting to a harsh environment as they do, merely reflect its harshness in their conduct, and that the Papago, seeking habitually to control environment in the interests of their kind as they do, are raised by their efforts to higher planes of humanity. The general relation between thought and surroundings was found to be of exceeding broad application, extending far beyond the local tribes. Indeed, it finds most definite expression in the current scientific teaching that knowledge arises in experience, and it seemed desirable to formulate the relation as a principle of knowledge which may appropriately be styled the responsivity of mind. The principle promises to be especially useful to ethnologists confronted with those suggestive similarities in artifacts, habits, and even languages, which were interpreted as evidences of former contact until their incongruity with geographic and other facts proved them to be coincidental merely, for the interdependence of thought and environment offers an adequate explanation of the coincidences, while the diminishing dependence of thought on environment with cultural advancement equally explains the preponderance of such coincidences among lowly peoples. A preliminary announcement of the results of the study has been made, but full publication is withheld pending further field work.

Mr. James Mooney spent the greater part of the fiscal year in elaborating for publication the extensive collection of material made by him among the Cherokee Indians several years ago. The collection comprises a nearly complete series of the myths and traditions of the tribe, cosmogonic, historical, interpretative, and trivial; for among the Cherokee, as among other primitive peoples, the traditions vary widely in character and purpose. Mr. Mooney's collections are peculiarly valuable in that they are so complete as to indicate the genesis and development of the tribal traditions. It would appear that the parent myth usually begins as a trivial story or fable, perhaps carrying a moral and thus introducing and fixing some precept for the guidance of conduct; the great majority of these fables drop out of the current lore within the generation in which they are born, but those chancing to touch the local life strongly or happening to glow with local genius survive and are handed down to later generations. The transmitted fables form a part of the lore repeated by the eldermen and elderwomen night after night to while away the long evenings by the camp fire, and in this way they become impressed on the memory and imagination of the younger associates; for under the conditions of prescriptorial life they come to take the place of learning and literature in the growing mind of the youth. In the successive repetitions the weaker fables are eliminated, while the more vigorous are gradually combined and eventually strung together in an order made definite by custom; at the same time they acquire sacredness with age, and some of them become so far esoteric that they may not be repeated by youths, or perhaps even by laymen, when they are the exclusive property of sages or shamans. Now the fable, per se, is seldom vigorous enough to pass unaided into the esoteric lore of the tribe; but when it serves to interpret some interesting natural phenomenon, either in its original form or in its subsequent association, it is thereby fertilized, and, with the combined vitality of fable and interpretation, enjoys greatly increased chance of survival. Sometimes the historical element is also added, when the composite intellectual structure is still further strengthened, and may persist until history blends with fancy painted prehistory, and the story becomes a full-fledged cosmogonic myth. Accordingly, the character and the age of myths are correlated in significant fashion. Mr. Mooney's memoir is incorporated in the Nineteenth Annual Report, which was sent to the printer on March 28, and proofs were in hand before the close of the fiscal year. Since it is the first of a series of memoirs on the Cherokee by the same author, it was thought well to preface the publication with an extended review of the history of the Cherokee Indians from the time of discovery up to the removal of a portion of the tribe to Indian Territory, and in collecting material for this historical sketch Mr. Mooney was able to throw new light, not only on the movements of the tribesmen themselves, but on the routes of travel taken by various explorers from De Soto down.

Although handicapped by illness, Mrs. Matilda C. Stevenson continued the preparation of the final chapters in her monograph on Zuñi mythology. The work was so nearly completed at the end of the fiscal year that it was assigned a definite place in the Twenty-first Annual Report.

Dr. Fewkes's observations on the winter ceremonies of the Hopi Indians yielded important data of the nature suggested in previous paragraphs, and on his return from the field he at once took up the preparation of a memoir designed for incorporation in an early report.

A notable acquisition of the year was the Pawnee ritual, known as the Hako, obtained by Miss Alice C. Fletcher. Its basis is one of those house ceremonies which hold so large a place in aboriginal thought; and it is so exceptionally full as to at once reveal some of the most strictly characteristic phases of primitive thought and illumine the simpler house rituals already recorded. It is cosmogonic in import, and thus reflects the faith of the tribe. At the same time its details indicate the tribal migrations for many generations. It reveals primitive notions concerning the origin of fire and the relations of this agency to deified animals. It comprises a partially archaic vocabulary which promises to throw light on tribal affinities, and it includes rhythmic and fundamental melodic features which contribute in important degree to knowledge of aboriginal music. The entire ritual, including the musical accompaniment, is well advanced in preparation for the Twentieth Report.

Dr. Cyrus Thomas continued the examination of Mayan and Mexican aboriginal number systems, with special reference to the Mayan and Mexican calendar systems. Early in 1900 he completed a memoir on the subject, entitled "Mayan Calendar Systems," which was incorporated in the Nineteenth Annual Report. Later in the fiscal year he continued in cognate work, making gratifying progress. One of the most interesting features of aboriginal culture to the scholars of the world is the series of highly developed calendaric systems extending from Mexico on the north to Peru on the south; these systems reflect a knowledge of astronomy considerably less advanced than that prevailing in Chaldea and Egypt at the beginning of written history, yet sufficiently advanced to indicate the beginnings of astronomic observation and generalization, and thus define a stage of scientific development of which the Old World record is practically lost. Accordingly Dr. Thomas's researches are deemed especially valuable to scholars.

As already noted, Mr. J. N. B. Hewitt has applied the comparative method to the study of aboriginal traditions with excellent results. During the closing months of the fiscal year he was occupied in revising his memoir on Iroquoian mythology, and incorporating certain important data obtained during his winter trip. The material is nearly ready for the press.

DESCRIPTIVE ETHNOLOGY.

Except during the time spent in field work, Mr. F. W. Hodge was occupied in arranging material for the Cyclopedia of Native Tribes and in editorial work. In the former task he was aided during a part of the year by Dr. Cyrus Thomas, and in the latter by Col. F. F. Hilder, ethnologic translator, and Mr. H. S. Wood, assistant editor. Dr. Thomas finished the revision of the Cyclopedia cards pertaining to the Siouan stock early in the fiscal year; accordingly this portion of the work is ready for publication save for the requisite editorial scrutiny. The plan for the Cyclopedia has been set forth in some detail in earlier reports and need not be repeated.

COLLECTIONS.

The collaborators engaged in field work made more or less extensive collections for use in their researches, and for subsequent transfer to the National Museum; and, in addition, a number of special collections were acquired. Conspicuous among these was the Hudson basketry collection, from California, for which negotiations were opened during the last fiscal year, though the material was received and installed during the current year; it is regarded as one of the most instructive collections of American aboriginal basketry extant, and its possession, in connection with the very considerable collections of corresponding ware already in the Institution, places the National Museum in a foremost position among the museums of the world so far as opportunities for study of primitive basketry are concerned. Another noteworthy collection was that of Mr. J. B. Hatcher in Patagonia, of which the final portions were received during the fiscal year, together with a good series of photographs illustrating the uses of artifacts, the construction of habitations, etc.; while various collections of objects required to complete series, etc., were acquired by purchase. Among the minor collections was an exceptionally fine one of copper implements from the Lake Superior region; these implements were noteworthy in that while of aboriginal design, the material was wrought with metal tools in such wise as to show the influence of Caucasian contact; so that the collection forms an instructive example of acculturation, and serves as a useful guide in the classification of other copper objects in the Museum. A particularly useful series of stone implements, known as the Steiner collection, was also among the acquisitions of the year.

Although collateral to the work of the Bureau, it is proper to report that Col. F. F. Hilder, ethnologic translator and acting chief clerk of the Bureau, was, on January 16, 1900, detailed to the Government Board of the Pan-American Exposition, and that under a commission from that Board he visited the Philippine Islands and made extensive collections of ethnologic and archæologic material, with the understanding that, after use during the exposition, a considerable portion of it should be transferred to the National Museum. Toward the close of the year Colonel Hilder reported the shipment of extensive collections, together with a good series of photographs, drawings, etc., designed for use in the installation. Incidentally he availed himself of opportunities to obtain certain useful ethnologic literature required for the library of the Bureau.

PROPERTY.

As explained in previous reports, the property of the Bureau is practically limited to (1) office furniture and other appurtenances to office work, (2) ethnologic manuscripts and other records of original work, (3) photographs and drawings of Indian subjects, (4) a small working library, (5) collections held temporarily by collaborators for use in research, and (6) undistributed residua of the editions of the Bureau publications. During the fiscal year there has been no noteworthy change in the amount or value of the office property; a considerable number of manuscripts (including two of special value noted in earlier paragraphs) have been added to the archives, either temporarily or permanently; over a thousand photographic negatives and several hundred prints and drawings have been added to the collection of illustrative material, while the library has maintained normal growth, chiefly through exchanges. There was no considerable accumulation or transfer of objective material required for study during the year, while there was a considerable reduction in the number of back Reports through the constantly increasing public demand for ethnologic literature.

PUBLICATION.

Mr. F. W. Hodge remained in charge of the editorial work, with the assistance of Col. F. F. Hilder during the earlier part of the year and of Mr. H. S. Wood during Colonel Hilder's absence in the Philippines. The second part of the Seventeenth Annual Report was received from the Government Printing Office during the year, though the first part was unfortunately delayed. The printing of the Eighteenth Report was practically completed. The Nineteenth Report was transmitted for publication on March 28, and the composition of this Report and also of the first bulletin of the new series was under way before the close of the fiscal year.

Mr. DeLancey Gill, the illustrator of the Bureau, remained in charge of the photographic work and of the preparation of copy for the frequently elaborate illustrations required in presenting adequately the results of the researches.

LIBRARY.

The work in the library of the Bureau was maintained under the supervision of Mr. Hodge. During the greater part of the fiscal year he had the assistance of Mrs. Lucretia M. Waring, who made good progress in the cataloguing of the books and pamphlets in accordance with the classification of anthropic science developed in the Bureau. The number of books and pamphlets on hand at the close of the fiscal year is about 12,000 and 4,000, respectively.

NECROLOGY.

It is with much sorrow that I have to report the death of Frank Hamilton Cushing, ethnologist in the Bureau, on April 10, 1900. Mr. Cushing was one of the most enthusiastic students of ethnology ever produced in America, and the spark of his genius illumined many problems of the science. His death was a blow to the Bureau and a loss to the world. A more extended obituary will be transmitted later.

On December 25, 1899, Dr. Elliott Coues died suddenly. While he was not an officer of the Bureau, he had frequently cooperated with the Director and the collaborators, especially during the earlier portion of the fiscal year, when he was attached to a party engaged in work in the pueblo region. An enthusiastic student of early American history, he was brought in frequent touch with ethnologists and ethnologic problems, thereby acquiring extended and accurate knowledge of the aborigines; hence his death was a serious loss to the science.

Dr. Walter J. Hoffman, for many years an attaché of the Bureau, died November 8, 1899. He entered the Bureau in its earlier years as an assistant to the late Col. Garrick Mallery, and spent some years in the collection of petroglyphs and other aboriginal records. Subsequently he made independent studies in different tribes, notably the Menominee of Wisconsin. His principal publications in the Bureau Reports are "The Midewiwin, or Grand Medicine Society of the Ojibwa," in the Seventh Report, and "The Menominee Indians," in the Fourteenth Report. His connection with the Bureau was temporarily severed in 1895, when he undertook certain special work for the United States National Museum; in 1897 he was appointed United States consul at Mannheim, Germany, where he availed himself of opportunities for study of aboriginal American collections and records. His health failing, he returned to his home near Reading, Pa., in the autumn of 1899, where his death occurred. Although he was but 53 years of age at the time of his death, he was one of the pioneers in American ethnology.

I have the honor to be, yours, with respect,

J. W. Powell, *Director.*

Mr. S. P. Langley,
Secretary Smithsonian Institution, Washington, D. C.

APPENDIX III.

REPORT ON THE OPERATIONS OF THE INTERNATIONAL EXCHANGE SERVICE FOR THE YEAR ENDING JUNE 30, 1900.

SIR: I have the honor to submit the following report upon the operations of the International Exchange Service for the year ending June 30, 1900.

About seven years ago extensive improvements were made in the basement of the eastern wing of the Smithsonian Building, and five communicating rooms were arranged expressly for the use of the Exchange Service and have since been so occupied. The general equipment of these offices consists of sorting and folding tables; bins for the geographical classification of exchanges contributed in the United States for distribution abroad; book cases for directories of the principal cities of the world, college year books, and other publications for ready reference; filing cases for index catalogues and cases for correspondence, exchange ledger accounts, and receipt cards for exchange packages, both foreign and domestic; necessary desks with customary equipments, a typewriter, copying press, etc. The property acquired during the year has consisted almost exclusively of boxes, packing materials, stationery, and other expendable supplies, the cost of which was $1,322.

The space originally assigned to the International Exchanges has not since been enlarged, although the work of late has materially increased. The duties of the service require the constant handling of heavy boxes and packages, necessitating frequent repairs to the floors, walls, and furniture, the expense of which is invariably borne by the Smithsonian Institution and not from the Congressional appropriations for the support of the Exchange Service.

Losses of exchanges occurred during the year by the burning and subsequent sinking of the steamship *Patria*, of the Hamburg-American Line, off the English coast on November 4, 1899, while en route from New York to Hamburg, the consignment consisting of three cases for Russia, three for Sweden, three for Austria, and one for Hungary. All contained miscellaneous publications for correspondents in those countries. Two cases of miscellaneous exchanges for Switzerland and one case of United States Government publications destined for the Bibliothèque Fédérale, Bern, were destroyed by fire while on the docks of the North German Lloyd Steamship Company at Hoboken, N. J., on June 30, 1900. All available duplicate publications to replace those destroyed by the burning of the steamship *Patria* were forwarded to the original addresses, and an attempt will be made to secure duplicates of those burned on the Hoboken docks. It is assumed that there will be no difficulty in procuring all contributions by individuals and societies, but a special act of Congress may be necessary in order to obtain the Congressional documents, inasmuch as their distribution is specific and no provision is made for replacing duplicates when losses occur in the manner above mentioned.

The comparative statements which follow in this report show in the aggregate a marked increase in the extent of transmissions during the year ending June 30, 1900, over those of the previous twelve months. The number of correspondents has been increased during the year by 2,982, and now aggregates 33,951. Of this number, 7,721 are in the United States. Fifteen thousand seven hundred and twenty-eight packages, or 92,108 pounds in weight, represent the increase in transmissions during the past year. This is equivalent to 16 per cent and 29 per cent, respectively. During this time 1,768 cases, representing 687 separate transmissions, or an average of more than 13 transmissions each week, were shipped abroad. Notwithstanding the increase in the number of shipments, the office routine has of late been so simplified as to enable the regular force employed in the Exchange office to distribute packages immediately after their receipt at the Institution, and, with the exception of the record division, in which the work has occasionally been behind, no part of the service has suffered.

The Government appropriation for the support of the International Exchanges during the fiscal year ending June 30, 1900, was $3,000 above that for the previous year. This increase, which has been applied mainly to transportation charges, has enabled the Institution to make use of the most expeditious carriers of freight and express from New York to the principal ports of all other countries, whereby its packages now reach their destination in much less time than formerly. This is a most decided improvement over the previous conditions, under which, with wholly insufficient means, the Institution was obliged to avail itself of the privileges so generously granted by such of the steamship companies as were willing to take its freight gratuitously or at greatly reduced rates, and to accept such service as the companies could afford to give on these terms. While the railroad service could be improved both in this country and in Europe by a somewhat increased expenditure. which, however, it is as yet impossible to make, the arrangements so far consummated by the Institution, both as to ocean transportation and the distribution of packages received from abroad for the United States, are fairly satisfactory.

Exchange relations with Spain, which were suspended during the continuance of the recent war with that country, have been reestablished, and by direction of the Spanish secretary of state, under date of September 30, 1899, the Ministerio de Fomento at Madrid has been designated to receive and distribute all parcels sent from the United States through the Smithsonian Institution, thus becoming the recognized medium of exchange in Spain.

Since the last report full exchange relations have been established between the United States and Costa Rica; but all efforts in the direction of inaugurating an official bureau for handling miscellaneous exchanges in Japan have so far failed, although the government of that country bears the expense of distributing such publications as are sent to the various governmental institutions and to individuals officially connected therewith.

For the past six months China, with a single exception, has been the only country in the world in which there have not been some means of distributing exchanges. Formerly the Zi-ka-wei Observatory at Shanghai attended to the matter, but it has lately been forced to decline further service. The Chinese minister at Washington has taken much interest in the International Exchange Service and has expressed himself not only in favor of sending regularly to this country the official publications of his government in exchange for the congressional and departmental documents of the United States, but also of establishing in China an official bureau through which exchanges could be distributed to institutions and individuals throughout the Empire. Until recently it was thought that negotiations were progressing favorably to this end, but the present condition of the Chinese Government will, it is feared, indefinitely postpone the consummation of this plan.

Messrs. William Wesley & Son, at London, Dr. Felix Flügel, at Leipsic, and Dr. Joseph von Körösy, at Budapest, continue in the service of the International Exchanges as salaried agents, and to them, as well as to the large number of agents who gratuitously serve the Institution in the distribution of exchanges, grateful acknowledgments are due.

Tabular statement of the work of the International Exchange Service during the fiscal year 1899–1900.

Date.	Number of packages handled.	Weight of packages handled.	Number of correspondents June 30, 1900.				Packages sent to domestic addresses.	Cases shipped abroad.
			Foreign societies.	Domestic societies.	Foreign individuals.	Domestic individuals.		
1899.								
July	8,230	34,676						
August	13,919	35,251						
September	5,753	19,968						
October	5,669	18,952						
November	8,766	26,903						
December	9,814	31,401						
1900.								
January	8,204	27,749						
February	8,722	70,217						
March	12,527	28,522						
April	12,495	60,218						
May	13,928	36,985						
June	5,516	19,149						
Total	113,563	409,991	10,845	2,721	15,385	5,000	28,625	1,768
Increase over 1898–99	15,728	92,108	523	125	2,007	327	[1] 2,020	268

[1] Decrease.

The following table shows the number of packages of exchanges handled and the increase in the number of correspondents each year from 1894 to 1900:

	1893–94.	1894–95.	1895–96.	1896–97.	1897–98.	1898–99.	1899–1900.
Number of packages received	97,969	107,118	88,878	81,162	84,208	97,835	113,563
Weight of packages received...lbs.	235,028	326,955	258,731	247,444	301,472	317,883	409,991
Ledger accounts:							
Foreign societies	6,991	8,751	8,022	9,414	10,165	10,322	10,845
Foreign individuals	8,619	9,609	10,878	12,013	12,378	13,378	15,385
Domestic societies	1,620	2,014	2,115	2,445	2,533	2,596	2,721
Domestic individuals	2,993	3,034	3,899	4,136	4,382	4,673	5,000
Packages to domestic addresses	32,931	29,111	34,091	23,619	21,057	30,645	28,625
Cases shipped abroad	905	1,364	1,043	1,300	1,330	1,500	1,768

CORRESPONDENTS.

The record of exchange correspondents at the close of the year contained 33,951 addresses, being an increase of 2,982 over the preceding year. The following table gives the number of correspondents in each country and also serves to illustrate the scope of the service:

Number of correspondents of the International Exchange Service in each country on June 30, 1900.

Country.	Correspondents.		
	Libraries.	Individuals.	Total.
AFRICA.			
Algeria	20	31	51
Angola	1	....	1
Azores	5	14	19
Beira	....	1	1
Canary Islands	1	6	7
Cape Colony	39	68	107
Cape Verde Islands	....	5	5
Egypt	27	50	77
French Kongo	....	1	1
Gambia	....	2	2
Gold Coast	....	2	2
Gorée-Dakar	....	3	3
Kongo Free State	....	3	3
Lagos	2	1	3
Liberia	2	5	7
Lorenzo-Marques	....	2	2
Madagascar	2	6	8
Madeira	3	3	6
Mauritius	11	6	17
Morocco	....	10	10
Mozambique	....	1	1
Natal	12	14	26
Orange Free State	....	1	1
Réunion	2	....	2
St. Helena	2	2	4
Sierra Leone	1	3	4
South African Republic	13	8	21
Tunis	6	8	14
Zanzibar	....	5	5
AMERICA (NORTH).			
Canada	242	435	677
Central America:			
British Honduras	4	7	11
Costa Rica	25	29	54
Guatemala	38	53	91
Honduras	9	25	34
Nicaragua	11	31	42
San Salvador	14	10	24
Greenland	2	....	2
Mexico	136	121	257
Newfoundland	12	14	26
St. Pierre-Miquelon	1	2	3
United States	2,721	5,000	7,721
AMERICA (NORTH)—continued.			
West Indies:			
Anguilla	....	1	1
Antigua	5	4	9
Bahamas	2	10	12
Barbados	8	10	18
Bermuda	3	13	16
Buen Ayre	....	1	1
Cuba	41	95	136
Curaçao	....	3	3
Dominica	1	7	8
Grenada	2	4	6
Guadeloupe	2	5	7
Haiti	6	16	22
Jamaica	11	34	45
Martinique	1	5	6
Montserrat	....	2	2
Nevis	....	1	1
Porto Rico	....	19	19
St. Bartholomew	....	2	2
St. Christopher	1	4	5
St. Croix	1	2	3
St. Eustatius	....	1	1
St. Martin	....	2	2
St. Lucia	2	3	5
St. Thomas	1	3	4
St. Vincent	1	2	3
Santo Domingo	2	10	12
Tobago	....	1	1
Trinidad	10	9	19
Turks Islands	1	5	6
AMERICA (SOUTH).			
Argentina	129	110	239
Bolivia	15	9	24
Brazil	103	128	231
British Guiana	14	9	23
Chile	75	77	152
Colombia	34	45	79
Dutch Guiana	2	2	4
Ecuador	13	20	33
Falkland Islands	....	4	4
French Guiana	....	2	2
Paraguay	12	7	19

Number of correspondents of the International Exchange Service in each country on June 30, 1900—Continued.

Country.	Correspondents.		
	Libraries.	Individuals.	Total.
AMERICA (SOUTH)—continued.			
Peru	32	54	86
Uruguay	39	25	64
Venezuela	31	38	69
ASIA.			
Arabia		7	7
Borneo		1	1
British Burma	7		7
British North Borneo		1	1
Celebes		1	1
Ceylon	20	10	30
China	37	80	117
Cochin China	4	4	8
Cyprus	2	3	5
Formosa		1	1
French East Indies	1	1	2
Hongkong	7	12	19
India	192	168	360
Japan	110	236	346
Java	13	29	42
Korea	1	7	8
New Guinea		1	1
Persia	3	8	11
Philippine Islands	7	10	17
Portuguese India	1		1
Siam	4	13	17
Straits Settlements	10	13	23
Sumatra		2	2
AUSTRALASIA.			
New South Wales	64	102	166
New Zealand	66	77	143
Queensland	32	42	74
South Australia	37	62	99
Tasmania	16	15	31
Victoria	92	113	205
Western Australia	12	19	31
EUROPE.			
Austria	653	831	1,484
Belgium	303	326	629
Bulgaria	12	10	22
Denmark	98	146	244
France	1,539	1,781	3,320
Germany	2,176	2,802	4,978
Gibraltar		4	4
Great Britain	1,709	3,728	5,437
Greece	37	36	73
Iceland	16	8	24
Italy	724	712	1,436
Luxemburg	8	2	10
Malta	8	11	19
Netherlands	178	230	408
Norway	117	112	229
Portugal	96	71	167
Roumania	30	46	76
Russia	431	665	1,096
Servia	17	12	29
Spain	154	166	320
Sweden	162	244	406
Switzerland	308	476	784
Turkey	33	72	105
POLYNESIA.			
Bismarck Archipelago		1	1
Fiji Islands	1	3	4
Hawaiian Islands	20	47	67
Marshall Islands		1	1
New Caledonia		2	2
New Hebrides	1		1
Samoa		5	5
Tahiti		3	3
Tonga		2	2
International	33		33
Total	13,566	20,385	33,951

EXCHANGE OF GOVERNMENT DOCUMENTS.

The following table shows the number of packages handled during the year for the several branches of the Government. By comparison with the last report it will be observed that there has been an increase this year of 49 per cent in the transmissions abroad and a decrease of nearly 35 per cent in the receipts. The packages enumerated as sent by the Library of Congress were those forwarded in conformity with the act of Congress of 1867.

Statement of Government exchanges during the year 1899–1900.

Name of bureau.	Packages.	
	Received for—	Sent by—
American Historical Association	14	10
Astrophysical Observatory	1	
Bureau of American Ethnology	217	58
Bureau of American Republics	9	4
Bureau of Education	88	
Bureau of Engraving and Printing	2	
Bureau of Medicine and Surgery	4	
Bureau of the Mint	3	307
Bureau of Navigation	4	
Bureau of Statistics, Treasury Department	70	3,662
Bureau of Steam Engineering, Navy Department	1	
Census Office	19	
Civil Service Commission	5	86
Coast and Geodetic Survey	87	256
Commissioner of Railroads	1	
Commissioners of the District of Columbia	2	14
Comptroller of the Currency	9	142
Department of Agriculture	444	76
Department of the Interior	32	595
Department of Justice	1	
Department of Labor	15	7
Department of State	29	13
Entomological Commission	5	
Fish Commission	97	380
General Land Office	5	
Geological Survey	519	7,799
Hydrographic Office	35	
Intercontinental Railway Commission	2	
Interstate Commerce Commission	7	28
Library of Congress	7,524	26,970
Light-House Board	6	88
Marine-Hospital Service	20	207
National Academy of Sciences	77	442
National Museum	261	1,900
National Zoological Park	5	1
Nautical Almanac Office	32	240
Naval Observatory	133	
Navy Department	10	
Office of the Chief of Engineers	33	85
Office of Indian Affairs	5	
Ordnance Office, War Department	1	
Patent Office	75	1,362
Post-Office Department	2	
President of the United States	1	
Record and Pension Office, War Department		291
Smithsonian Institution	2,074	1,325
Superintendent of Documents	1	1,349
Surgeon-General's Office (Army)	171	349
Treasury Department	9	443
War Department	53	15
Weather Bureau	69	693
Total	12,289	49,197

RELATIVE INTERCHANGE OF PUBLICATIONS BETWEEN THE UNITED STATES AND OTHER COUNTRIES.

Following is a comparative statement of exchange transmissions by packages between the United States and other countries during the years 1899 and 1900:

Comparative statement of packages received for transmission through the International Exchange Service during the fiscal years ending June 30, 1899, and June 30, 1900.

Country.	1899.		1900.	
	Packages.		Packages.	
	For—	From—	For—	From—
Algeria	116	56	96	8
Angola	1			
Antigua	4		8	
Arabia			3	
Argentina	1,534	492	3,127	308
Austria-Hungary	3,578	1,381	4,387	2,125
Azores	10		6	
Bahamas	11		8	
Barbados	5		7	1

Comparative statement of packages received for transmission through the International Exchange Service, etc.—Continued.

Country.	1899.		1900.	
	Packages.		Packages.	
	For—	From—	For—	From—
Belgium	1,701	1,382	2,148	1,564
Bermudas	8	....	27	....
Bolivia	26	....	79	....
Brazil	903	409	1,385	803
British America	2,060	1,281	2,479	1,396
British Burma	2	....	1	1
British Guiana	37	1	51	....
British Honduras	4	....	5	....
Bulgaria	55	1	63	1
Canary Islands	1	....	....	....
Cape Colony	194	3	210	8
Ceylon	46	....	49	....
Chile	718	....	1,106	211
China	155	148	238	173
Colombia	356	....	704	14
Costa Rica	214	295	922	478
Cuba	204	11	196	22
Curaçao	....	....	1	....
Cyprus	3	....	1	....
Denmark	777	127	1,067	266
Dominica	3	....	2	....
Dutch Guiana	5	....	4	....
Ecuador	61	....	74	....
Egypt	88	21	96	....
Falkland Islands	....	....	1	....
Fiji Islands	1	....	3	....
Formosa	....	....	1	....
France	7,022	3,129	7,178	3,458
French Cochin China	....	....	1	....
Friendly Islands	27	....	....	....
Germany	11,219	6,018	12,576	6,139
Gibraltar	....	....	2	....
Gold Coast	4	....	....	....
Grenada	3	....	6	....
Great Britain and Ireland	10,411	13,603	10,843	8,950
Greece	395	....	2,037	....
Greenland	7	....	2	....
Guadeloupe	2	....	2	....
Guatemala	65	....	144	....
Guinea	1	....	....	....
Haiti	283	....	565	....
Hawaiian Islands	85	12	71	8
Honduras	12	72	41	267
Hongkong	23	....	82	....
Iceland	49	....	35	1
India	1,069	89	1,371	154
Italy	3,391	1,334	3,862	992
Jamaica	67	....	76	....
Japan	955	52	1,394	20
Java	152	66	151	124
Korea	1	....	19	....
Lagos	1	....	1	....
Liberia	26	....	32	....
Lourenço Marquez	1	....	....	....

Comparative statement of packages received for transmission through the International Exchange Service, etc.—Continued.

Country.	1899.		1900.	
	Packages.		Packages.	
	For—	From—	For—	From—
Luxemburg	64		55	
Madagascar	4		11	
Madeira	4		1	
Malta	34		35	
Martinique	4		3	
Mauritius	59		37	
Mexico	1,506	1,418	1,641	4,099
Montenegro			1	
Morocco			1	
Natal	28		46	5
Netherlands	1,392	543	1,662	533
New Caledonia			1	
Newfoundland	25		37	
New Hebrides			1	
New South Wales	1,113	261	1,390	360
New Zealand	572	6	834	5
Nicaragua	35		51	
Norway	1,039	259	1,237	383
Paraguay	18		39	13
Persia	3		22	
Peru	419	186	724	25
Philippine Islands	47		58	
Porto Rico			10	
Portugal	635	500	912	
Queensland	528		814	
Reunion	13		7	
Roumania	110	110	189	101
Russia	2,515	1,033	2,951	779
St. Bartholomew			1	
St. Croix			1	
St. Helena	6		2	
St. Kitts	1		1	
St. Martin			1	
St. Thomas			1	
St. Vincent	1		3	
Samoa			12	
Santa Lucia	3		3	
Santo Domingo	2		7	
San Salvador	53		53	24
Servia	43	46	36	1
Siam	38		57	
Sierra Leone	1		2	
Society Islands			1	
South African Republic	1,782		594	104
South Australia	491	43	781	39
Spain	450		1,212	
Straits Settlements	46		34	
Sumatra	1		1	
Sweden	1,512	280	1,916	493
Switzerland	1,847	615	2,120	726
Syria	18		11	
Tasmania	364		644	2
Tonga			26	

Comparative statement of packages received for transmission through the International Exchange Service, etc.—Continued.

Country.	1899.		1900.	
	Packages.		Packages.	
	For—	From—	For—	From—
Trinidad	57	....	77	....
Tunis	8	....	11	....
Turkey	76	....	621	....
Turks Islands	4	....	2	....
United States	30,645	62,184	28,625	76,264
Uruguay	539	237	817	116
Venezuela	379	....	699	1
Victoria	825	131	1,101	517
West Australia	324	....	790	....
Zanzibar	....	....	2	....

The following is a list of the Smithsonian correspondents acting as distributing agents, or receiving publications for transmission to the United States, and of countries receiving regularly exchanges through the Institution:

Algeria. (*See* France.)
Angola. (*See* Portugal.)
Argentina: Museo Nacional, Buenos Ayres.
Austria: K. K. Statistische Central-Commission, Wien.
Azores. (*See* Portugal.)
Belgium: Commission Belge des Échanges Internationaux, Brussels.
Bolivia: Oficina Nacional de Inmigración, Estadística y Propaganda Geográfica, La Paz.
Brazil: Bibliotheca Nacional, Rio de Janeiro.
British Colonies: Crown Agents for the Colonies, London, England.
British Guiana. (*See* British Colonies.)
British Honduras. (*See* British Colonies.)
Bulgaria: Dr. Paul Leverkühn, Sofia.
Canada: Packages sent by mail.
Canary Islands. (*See* Spain.)
Cape Colony: Superintendent of the Stationery Department, Cape Town.
Chile: Universidad de Chile, Santiago.
China. (Shipments suspended for the present.)
Colombia: Biblioteca Nacional, Bogotá.
Costa Rica: Oficino de Depósito, Reparto y Canje Internacional, San José.
Cuba: Dr. Vicente de la Guardia, Habana.
Denmark: Kong-Danske Videnskabernes Selskab, Copenhagen.
Dutch Guiana: Surinaamsche Koloniale Bibliotheek, Paramaribo.
Ecuador: Biblioteca Nacional, Quito.
East India: India Store Department, India Office, London.
Egypt: Société Khédiviale de Géographie, Cairo.
Fiji Islands. (*See* British Colonies.)
France: Bureau Français des Échanges Internationaux, Paris.
Friendly Islands: Packages sent by mail.
Germany: Dr. Felix Flügel, Wilhelmstrasse 14, Leipzig-Gohlis.
Gold Coast. (*See* British Colonies.)
Great Britain and Ireland: William Wesley & Son, 28 Essex street, Strand, London, England.
Greece: Prof. R. B. Richardson, Director, American School of Classical Studies, Athens.
Greenland. (*See* Denmark.)

Guadeloupe. (*See* France.)
Guatemala: Instituto Nacional de Guatemala, Guatemala.
Guinea. (*See* Portugal.)
Haiti: Secrétaire d'Etat des Relations Extérieures, Port au Prince.
Hawaiian Islands: Foreign Office, Honolulu.
Honduras: Biblioteca Nacional, Tegucigalpa.
Hungary: Dr. Joseph von Körösy, "Redoute," Budapest.
Iceland. (*See* Denmark.)
Italy: Biblioteca Nazionale Vittorio Emanuele, Rome.
Jamaica. (*See* British Colonies.)
Java. (*See* Netherlands.)
Korea: Packages sent by mail.
Leeward Islands. (*See* British Colonies.)
Liberia: Care of American Colonization Society, Washington, District of Columbia.
Luxemburg. (*See* Germany.)
Madagascar. (*See* France.)
Madeira. (*See* Portugal.)
Malta. (*See* British Colonies.)
Mauritius. (*See* British Colonies.)
Mexico: Packages sent by mail.
Mozambique. (*See* Portugal.)
Natal: Agent-General for Natal, London, England.
Netherlands: Bureau Scientifique Central Néerlandais, Den Helder.
New Guinea. (*See* Netherlands.)
New Hebrides: Packages sent by mail.
Newfoundland: Packages sent by mail.
New South Wales: Government Board for International Exchanges, Sydney.
New Zealand: Colonial Museum, Wellington.
Nicaragua: Ministerio de Relaciones Exteriores, Managua.
Norway: Kongelige Norske Frederiks Universitet, Christiania.
Paraguay: Care Consul-General of Paraguay, Washington, District of Columbia.
Persia. (*See* Russia.)
Peru: Biblioteca Nacional, Lima.
Philippine Islands: Packages sent by mail.
Portugal: Bibliotheca Nacional, Lisbon.
Queensland: Chief Secretary's Office, Brisbane.
Roumania. (*See* Germany.)
Russia: Commission Russe des Échanges Internationaux, Bibliothèque Impériale Publique, St. Petersburg.
Saint Helena. (*See* British Colonies.)
Santo Domingo: Packages sent by mail.
San Salvador: Museo Nacional, San Salvador.
Servia. (*See* Germany.)
Siam: Board of Foreign Missions of the Presbyterian Church, New York.
South African Republic: William Wesley & Son, 28 Essex street, Strand, London.
South Australia: Astronomical Observatory, Adelaide.
Spain: Oficina para el Canje de Publicaciones Oficiales, Cientificas y Literarias. Seccion de Propiedad Intelectual del Ministerio de Fomento, Madrid.
Straits Settlements. (*See* British Colonies.)
Sumatra. (*See* Netherlands.)
Syria: Board of Foreign Missions of the Presbyterian Church, New York.
Sweden: Kongliga Svenska Vetenskaps Akademien, Stockholm.
Switzerland: Bibliothèque Fédérale, Berne.
Tasmania: Royal Society of Tasmania, Hobart.

Trinidad. (*See* British Colonies.)
Tunis. (*See* France.)
Turkey: American Board of Commissioners for Foreign Missions, Boston, Massachusetts.
Turks Islands. (*See* British Colonies.)
Uruguay: Oficina de Depósito, Reparto y Canje Internacional, Montevideo.
Venezuela: Museo Nacional, Carácas.
Victoria: Public Library, Museum, and National Gallery, Melbourne.
Western Australia: Victoria Public Library, Perth.
Zanzibar: Packages sent by mail.

The distribution of exchanges to foreign countries was made in 1,768 cases, 239 of which contained official documents for authorized depositories, and the contents of 1,529 cases consisted of Government and other publications for miscellaneous correspondents. Of the latter class of exchanges the number of cases sent to each country is given below.

Argentina	36
Austria	74
Belgium	46
Bolivia	4
Brazil	14
British Colonies	14
Cape Colony	3
China	2
Chile	11
Colombia	5
Costa Rica	5
Cuba	5
Denmark	17
Dutch Guiana[1]	
East India	15
Ecuador	7
Egypt	2
France and colonies	169
Germany	238
Great Britain and Ireland	341
Greece	28
Guatemala	5
Haiti	1
Honduras	3
Hungary	25
Italy	74
Japan	19
Liberia	2
Mexico[2]	
Natal[3]	
New South Wales	19
Netherlands	34
New Zealand	10
Nicaragua	4
Norway	22
Paraguay	2
Peru	7
Polynesia[2]	
Portugal	14
Queensland	7
Roumania[4]	
Russia	60
Salvador	3
Servia[4]	
Siam	1
South Australia	14
South African Republic[3]	
Spain	26
Sweden	48
Switzerland	42
Syria	3
Tasmania[3]	
Turkey	6
Uruguay	6
Venezuela	5
Victoria	14
Western Australia	17

The following is a list of depositories of regular sets of United States Government publications forwarded abroad through the International Exchange Service on August 1, November 1, and December 30, 1899, and on March 12 and May 14, 1900:

Argentina: Library of the Foreign Office, Buenos Ayres.
Austria: K. K. Statistische Central-Commission, Wien.

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[1] Included in transmissions to Netherlands.

[2] Packages sent by mail.

[3] Included in transmissions to Great Britain.

[4] Included in transmissions to Germany.

Baden: Universitäts-Bibliothek, Freiburg.
Bavaria: Königliche Hof-und Staats-Bibliothek, München.
Belgium: Bibliothèque Royale, Brussels.
Brazil: Bibliotheca Nacional, Rio de Janeiro.
Buenos Ayres: Library of the Government of the Province of Buenos Ayres, La Plata.
Canada: Parliamentary Library, Ottawa.
Canada: Legislative Library, Toronto.
Chile: Biblioteca del Congreso, Santiago.
Colombia: Biblioteca Nacional, Bogotá.
Costa Rica: Oficina de Depósito, Reparto y Canje Internacional, San José.
Denmark: Kongelige Bibliotheket, Copenhagen.
England: British Museum, London.
France: Bibliothèque Nationale, Paris.
Germany: Deutsche Reichstags-Bibliothek, Berlin.
Greece: National Library, Athens.
Haiti: Secrétaire d'Etat des Relations Extérieures, Port au Prince.
Hungary: Hungarian House of Delegates, Budapest.
India: Secretary to the Government of India, Calcutta.
Italy: Biblioteca Nazionale Vittorio Emanuele, Roma.
Japan: Foreign Office, Tokyo.
Mexico: Museo Nacional, Mexico.
Netherlands: Library of the States General, The Hague.
New South Wales: Government Board for International Exchanges, Sydney.
New Zealand: General Assembly Library, Wellington.
Norway: Departementet for det Indre, Christiania.
Peru: Biblioteca Nacional, Lima.
Portugal: Bibliotheca Nacional, Lisbon.
Prussia: Königliche Bibliothek, Berlin.
Queensland: Parliamentary Library, Brisbane.
Russia: Imperial Public Library, St. Petersburg.
Saxony: Königliche Bibliothek, Dresden.
South African Republic: Department of Foreign Affairs, Pretoria.[1]
South Australia: Parliamentary Library, Adelaide.
Spain: Seccion de Propiedad Intelectual del Ministerio de Fomento, Madrid.
Sweden: Kongliga Biblioteket, Stockholm.
Switzerland: Bibliothèque Fédérale, Berne.
Tasmania: Parliamentary Library, Hobart.
Turkey: Minister of Public Instruction, Constantinople.
Uruguay: Oficina de Depósito, Reparto y Canje Internacional de Publicaciones, Montevideo.
Venezuela: Biblioteca Nacional, Carácas.
Victoria: Public Library, Melbourne.
Western Australia: Victoria Public Library, Perth.
Württemberg, Königliche Bibliothek, Stuttgart.

Respectfully submitted.

RICHARD RATHBUN,
Assistant Secretary.

Mr. S. P. LANGLEY,
Secretary of the Smithsonian Institution.

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[1] Shipments subsequent to August 1, 1899, suspended.

APPENDIX IV.

REPORT OF THE SUPERINTENDENT OF THE NATIONAL ZOOLOGICAL PARK.

SIR: I have the honor to herewith submit the following report relating to the condition and operations of the National Zoological Park for the year ending June 30, 1900.

At the close of that period the approximate value of the property belonging to the park was as follows:

Buildings for animals	$57,000
Buildings for administrative purposes	12,000
Office furniture, fixtures, and books	2,600
Machinery, tools, and implements	2,000
Fences and outdoor inclosures	25,000
Roadways, paths, rustic seats, etc	46,000
Nurseries	1,000
Horses	800
Animals in zoological collection	32,000

A detailed list of the animals in the collection is appended hereto. They may be classified as follows:

	Indigenous.	Foreign.	Domesticated.	Total.
Mammals	323	80	82	485
Birds	123	39	62	224
Reptiles	94	36		130
Total	540	155	144	839

The accessions of animals during the year have been as follows:

Presented	121
Received from Yellowstone National Park	17
Purchased and collected	103
Lent	42
Received in exchange	37
Born in National Zoological Park	124
Total	444

The cost for purchase, collection, and transportation of these accessions has been $4,400. Besides this there has been spent for books, photographs, apparatus, and office furniture the sum of $1,100.

The following improvements have been made in the buildings during the year:

Principal animal house.—The floor, hastily constructed of cheap material in 1891, has been relaid throughout, a new boiler and an enlarged heating plant suitable for maintaining the temperature necessary for tender tropical animals has been installed, and the stairway at the eastern end has been rebuilt so as to offer more convenient access to the boiler room. Cost, $1,400.

Antelope house.—The east wing of this structure, left unfinished for want of funds, has been completed and furnished with suitable cages. The cages along the western front have also been fitted with steel bars and a series of open-air paddocks built along the west side. A cement floor has been laid, extending under the cages. Total cost, $2,500.

Aquarium.—The old pumps received from the Fish Commission with the general plant being worn out, new salt-water pumps with hydraulic motors were supplied. A steam boiler with coil for heating salt water was put in, a tank for cooling the water also constructed, and a thermostat installed that controls the temperature of the water within 2° F. For transporting salt water a new outfit of cans was purchased. The supply is brought from Norfolk by steamer. Total cost, $900.

Temporary house for birds.—There being no suitable house for birds in the park, the small frame building formerly used for dogs was fitted up with outside cages and bathing pools. It is far from being satisfactory, as there is no means for heating it. The hardier species of birds, together with some that should be supplied with better protection, were housed here for the winter. Cost, $650.

New paddocks and sheds for moose, caribou, fallow deer, and arctic foxes.—The accession of these new species made it necessary to construct paddocks and shelters near the western entrance of the park, each provided with a pool or other water supply. Cost, $1,400.

Cage for harpy eagle.—A commodious open-air cage was built for this fine bird at a cost of $150.

Fence for buffalo paddocks.—The strong iron fence built for the bison was unsatisfactory as it has been much bent and injured by the frequent plunging and butting of these powerful animals. It has been replaced by a Page wire fence stretched between iron posts. The resiliency of this structure makes it much less liable to injury, and the animals attack it much less frequently than they do a stiff resisting fence. Cost, $1,000.

Driveway along Rock Creek.—This road, provided for by a special clause in the act appropriating funds for the park, has been continued by making a short connecting branch under the Klingle bridge, by repairing the damage done by the ice jam in the winter of 1898–99, by completing the masonry dam required for the protection of the roadway at the lower ford near the site where formerly stood the Adams mill, and by making the ford practicable for carriages. As several serious accidents have occurred through attempts to cross at the fords on this road during high water, posts and chains have been placed on either bank near the fords and access to them is prevented during a dangerous condition of the stream. The cost of the extension of this driveway was equal to the amount appropriated, viz, $5,000.

Main driveway.—This was resurfaced with gravel from Quarry Road bridge to the concourse, at a cost of $400.

Walks.—In front of the new outer yards at the antelope house a crushed-stone walk was made connecting with the general system, at a cost of $300.

Repairing damages of storm.—On June 2, 1900, there occurred a remarkable and unprecedented rainfall, nearly 3¾ inches falling during two hours. This did much damage to the roads and waterways in the park, especially on the eastern side, where the raw condition of the banks of earth made for the grading of the contiguous city roads caused hundreds of tons of gravel and débris to be precipitated upon the park, filling up the pelican pond, tearing down fences, destroying gutters and drain pipes, etc. The repair of this damage and the resurfacing of the roadways and walks cost $1,400.

Care of grounds.—The general care of the grounds, including the trimming of forest growth, removal of dead and injured trees, thinning and pruning, the care and transportation of nursery stock, etc., cost $700.

BOUNDARY OF THE PARK.

The following legislation has been enacted affecting the boundaries of the park:

> For the purpose of opening Cathedral avenue in accordance with the highway extension plans, the Secretary of the Interior is hereby authorized and directed to convey all right and title of the United States in and to a parcel of land bounded on the north by block two of the subdivision called Meridian Hill, and on the east by the east line of said block two extended southward, and on the west by the east line of Sixteenth street west, as said line is now extended and laid down through said block two, and on the south by a line parallel to W street of the city of Washington and distant ninety feet north from the south line of said W street, to the parties owning a good and unincumbered title in fee simple to lots numbered twenty-two to twenty-nine, both inclusive, in block numbered five of the subdivision called Woodley Park, in the District of Columbia, containing about one hundred and three thousand five hundred square feet of land, and adjoining the land of the United States embracing the Zoological Park, upon the conveyance by said parties of the said lots to the United States: *Provided*, That said lots in said Woodley Park, when so conveyed to the United States, as aforesaid, shall become a part of the said Zoological Park and shall be subject to the inclusion of so much of the same on said Cathedral avenue as may be necessary for the purpose of opening the said avenue. (Sundry civil act, July 1, 1898.)
>
> For grading and regulating Cathedral avenue from Connecticut avenue to Woodley road and the highway along the west border of the Zoological Park from Woodley road to Cathedral avenue, as shown on the plan of the permanent system of highways, third section, twenty-one thousand dollars: *Provided*, That parties interested first deposit with the collector of taxes of the District of Columbia an equal sum to be used toward defraying the cost of the work: *And provided*, That the full width of the highway bordering the Zoological Park be donated to the District of Columbia whenever it lies within the limits of Woodley Park. And the Commissioners of the District of Columbia are hereby authorized to use as a highway so much of the Zoological Park as lies within the lines of said proposed highway. (District act, June 6, 1900.)

A sketch map showing the several successive alterations of the boundary of the park in this region is herewith appended.

Removal of trees from Cathedral avenue.—It will be noted that the most recent legislation cedes to the District of Columbia a strip of ground required for Cathedral avenue. This strip was planted during 1891 and 1892 with fine evergreen trees, which have grown well and are now large and very valuable specimens. These have been carefully removed by special apparatus so as to disturb the roots as little as possible, and replanted in various situations throughout the park where needed, at a cost of $1,100.

The amount appropriated for the park during the year was $75,000, of which $5,000 was for continuing the driveway along Rock Creek already mentioned and $5,000 for widening the Adams Mill road near the entrance to the park. It will be remembered that this road is partly without, partly within, the park. The terms of the act refer to the portion *without* the park and are as follows:

> And five thousand dollars shall be expended in widening the Adams Mill road entrance to the Zoological Park from the corner of Eighteenth street and Columbia road, by acquiring by purchase or condemnation of land sufficient to widen the same to a width of one hundred feet, and such road, so widened, shall form a parkway under the control of the Zoological Park. (Sundry civil act, March 3, 1899.)

An estimated valuation of the property affected by the widening prescribed by this act showed that the sum appropriated was far from adequate for its purchase. It was also found that there would necessarily be some difficulty in placing a residential street under the control of the Zoological Park owing to the municipal regulations concerning water, gas, sewers, etc. It was therefore deemed best to defer action until the sense of Congress could be had concerning the matter. During the last session the law was changed by the following legislation:

> The unexpended balance of the amounts, aggregating eight thousand dollars, heretofore appropriated for widening, grading and regulating Adams Mill road from Columbia road to the Zoological Park entrance is hereby reappropriated, to be

> expended under the direction of the Commissioners of the District of Columbia; and the control of Adams Mill road is hereby vested in the said Commissioners of the District of Columbia and all proceedings necessary to purchase or condemn the land necessary to widen said road as authorized by act approved March third, eighteen hundred and ninety-nine, providing for sundry civil expenses of the Government for the fiscal year ending June thirtieth, nineteen hundred, and for other purposes, shall be taken by said Commissioners. (Sundry civil act, June 6, 1900.)

It is hoped that the provisions of this act may result in an improvement of the city roads giving access to the park. At present they are far from satisfactory.

The improvement of the Adams Mill road (without the park) has been necessarily delayed owing to the advance of property and the above-mentioned difficulties. A similar condition has prevailed at the western entrance to the park, near Connecticut avenue extended. An appropriation was made some years ago for the widening and improvement of this street, but it appears to have been insufficient as the work has never been completed. Its unfinished aspect greatly mars the approach to the park, and during wet weather the road, which has not been macadamized, becomes very muddy and unpleasant for carriages. As the roads within the park are among the best in the District and give access to beautiful drives in the upper park along Rock Creek, it seems highly desirable that this condition should not continue.

It should be noted that the act appropriating funds for the District of Columbia has this year provided for a road to be led along the left bank of the creek, finally abutting upon the park at the situation shown upon the annexed map. The exact terms of this act are as follows:

> To construct a masonry retaining wall between Cincinnati street and Woodley road to define the limits of a new driveway, which the Commissioners of the District of Columbia are hereby authorized to lay out along the east side of Rock Creek from Connecticut avenue to Zoological Park, four thousand dollars: *Provided*, That all land within the limits of said highway between Cincinnati street and Woodley road shall first be dedicated to the District of Columbia. (District act June 6, 1900.)

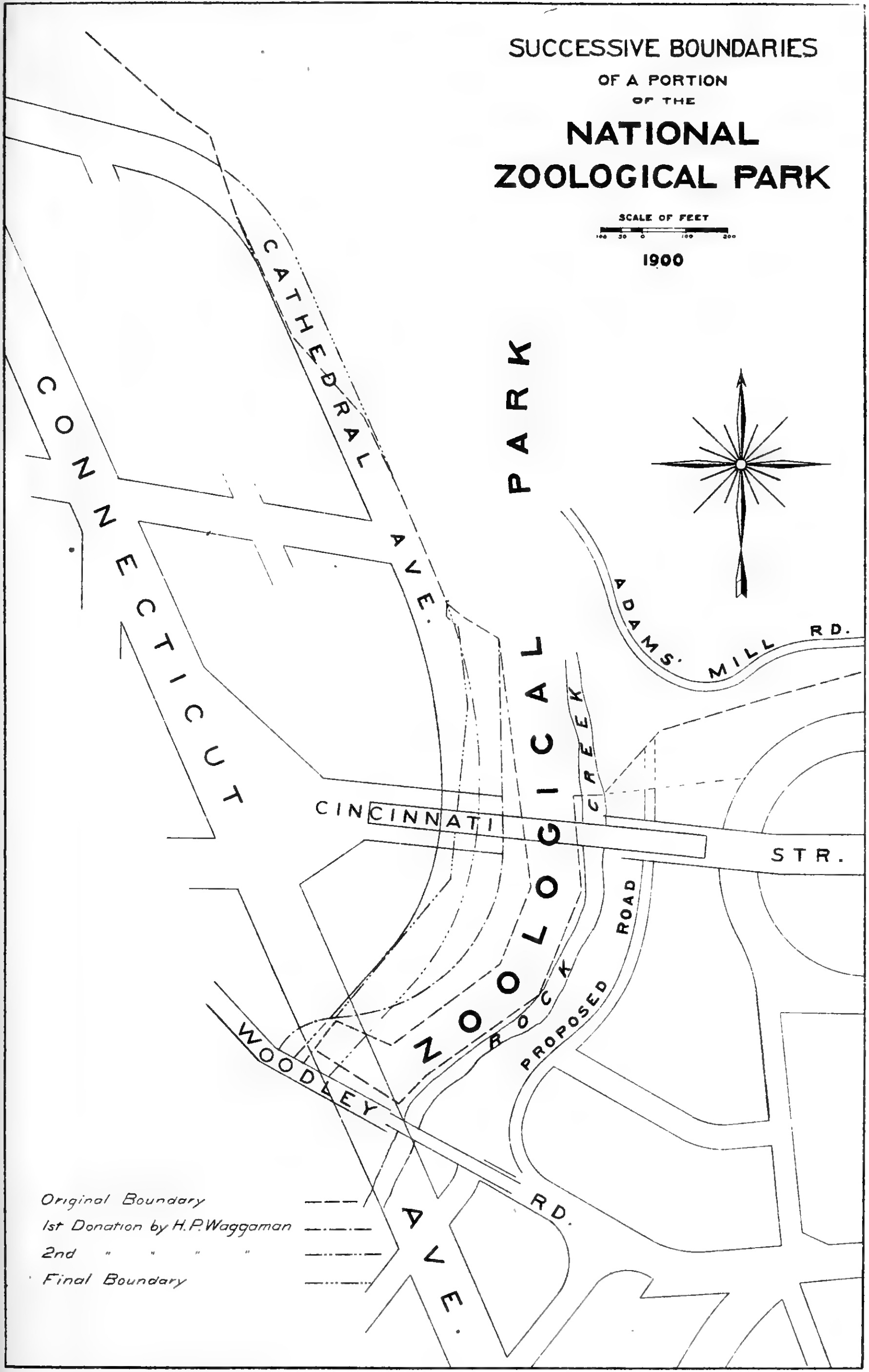
In the report of two years ago it was mentioned that the bridge over Rock Creek near the Quarry road entrance had begun to show signs of decay. This has increased alarmingly, and it was thought best to have the structure examined by an expert engineer. Mr. H. R. Leonard, of Philadelphia, a civil engineer recommended by the bridge department of the Pennsylvania Railroad Company, made a report on the structure to the effect that it was unsafe and should be immediately replaced by a new one. Heavy traffic over the bridge was at once stopped and Congress was asked to appropriate the sum of $10,000 for an iron bridge. Afterwards, owing to the advance in price of iron, it was asked that this amount be increased to $12,000. It was finally determined by Congress that a bridge either of natural or artificial stone should be constructed, and the sum of $22,000 was appropriated for the purpose. The construction will be conducted under the direction of the engineer Commissioner of the District of Columbia.

The question of completely inclosing the park with a boundary fence has been considered during the year. The fence built in 1890 was not completed at the lower portion along the banks of Rock Creek, and was never extended across the roads at the various entrances. Besides this, successive changes of boundary and the construction of roads along the boundary line at the lower end of the park have made it necessary to remove the fence in that region. It should also be noted that even where the fence is complete it affords no effective barrier against predatory dogs and cats. In consequence of this, several accidents to animals have occurred. The number of attacks of dogs up to June 30, 1900, is as follows:

August, 1891, Virginia deer seriously injured by dogs.

October 10, 1891, prong-horn antelope, frightened by dogs, ran into fence of paddock and broke its neck.

October 3, 1892, two South American deer killed by three dogs.



SUCCESSIVE BOUNDARIES
OF A PORTION
OF THE
NATIONAL
ZOOLOGICAL PARK

1900

THE NORRIS PETERS CO. PHOTO-LITHO. WASHINGTON, D. C.

March 31, 1896, three goats killed by dogs.

December, 1897, mule deer buck, frightened by dogs, ran into fence, broke its horns, tore off one hoof, and was otherwise so badly injured that it never recovered.

January, 1900, pack of dogs killed two deer and injured four, three of which died in consequence.

The cats prey upon the wild birds, squirrels, and other small animals, and are even a source of danger for some of the captive colonies of ground squirrels and prairie dogs. Attempts have been made to remedy this by increasing the force of watchmen, by strewing poisoned meat near the deer pens, and by removing from the park all domestic dogs which attract their kind. The most effectual remedy would of course be a dog and cat tight fence with guarded gates. An appropriation of $20,000 for a fence of this character was asked of Congress, but has not yet been granted.

It should be noted, moreover, that the maintenance of guarded entrance gates involves an increase in the number of watchmen and the advantage gained seems hardly commensurate with the annual expense required, for even with the best repairs the old fence will not prove an effective barrier.

The expense of a thoroughly protective fence inclosing the entire park is undoubtedly an obstacle to its erection. If it is impracticable to make so large an inclosure, I would still recommend that a considerable section of the more secluded portion of the grounds be thus fenced off. This would be of the greatest value for the exhibition of game birds of all species, for deer, antelope, rabbits, squirrels, etc.

The situation of the park at the bottom of a deep valley, while it adds to its seclusion, entails some disadvantages. The city roads that lead into it are steep in grade, and during great storms like that of June 2, 1900, the storm water is precipitated in torrents upon the park, bringing down tons of débris that clog the pipes and overwhelm the roads. The only effective remedy for this is the construction of culverts of sufficient size to readily carry into the creek all the water that may fall. The raw slopes of the city streets that lie on a higher level than the park to the eastward continue to be a great source of annoyance, as large quantities of red mud wash down from them upon the park grounds after every heavy rain.

During the year the District Commissioners constructed a sewer from Ontario avenue through the park, connecting with the intercepting sewer formerly constructed by them. The point where this sewer enters the park at Ontario avenue should be protected by a proper retaining wall. Such a wall should also be built along Klingle road, where the little stream that follows the park boundary for a short distance has cut into the road.

The circular sent to officers abroad with reference to collecting animals for the National Zoological Park has elicited some very satisfactory responses. Mr. E. S. Cunningham, United States consul at Aden, Arabia, states that wild animals can be procured in that vicinity at low rates and that transportation to New York can be had without great difficulty. Two young lions and two beautiful young leopards have already been secured by his efforts. The consul at Maracaibo has secured free transportation for his animals and has offered to attend to procuring them. The consul at Singapore sends a list of animals that may be procured at that port, with prices of the same, which are far below those at which the same animals can be obtained here. Other officers abroad have also offered to procure animals.

Mr. M. W. Gibbs, the consul at Madagascar, collected some of the rare animals of that region, expecting to deliver them to the U. S. S. *Chicago*, whose commanding officer had been instructed by the Navy Department to transport them for the park. However, for some reason not clearly understood, the officer in command of the *Chicago* refused to take the animals. The bubonic plague shortly appeared in Madagascar, the shipment of animals then became impracticable, and it therefore became necessary to release them.

Through the good offices of the consul at Winnipeg, Manitoba, a fine pair of young moose was procured for the park, and the consul at St. Johns, Newfoundland, has undertaken to procure a pair of the little-known Newfoundland caribou (*Rangifer terræ-novæ*). Mr. K. K. Kenneday, consul at Para, Brazil, secured a valuable collection of eighteen small mammals and birds from his excellency the governor of the province. A large female tapir belonging to this collection died en route.

Other contributors have been as follows:

Brig. Gen. James H. Wilson, U. S. V., commanding the Department of Matanzas and Santa Clara, Cuba: Ten flamingoes, and on behalf of Gen. Dantin y Feliz, a pair of jutia-conga.

Lieut. Commander W. H. H. Southerland, U. S. N., commanding U. S. S. *Scorpion:* Two crab-eating raccoons, obtained off the mouth of the Orinoco River.

Lieut. William A. Lieber, jr., U. S. A.: A black ape and a moor macaque, obtained by him while serving in the Philippines.

Lieut. Roger Welles, jr., U. S. N.: A young Baird's tapir, obtained on the Isthmus of Panama.

Capt. George F. Chase, U. S. A.: A Philippine deer.

Alfred Benitz, Calchaqui, Argentine Republic, through James M. Ayers, United States consul at Rosario, a very fine female white-lipped peccary.

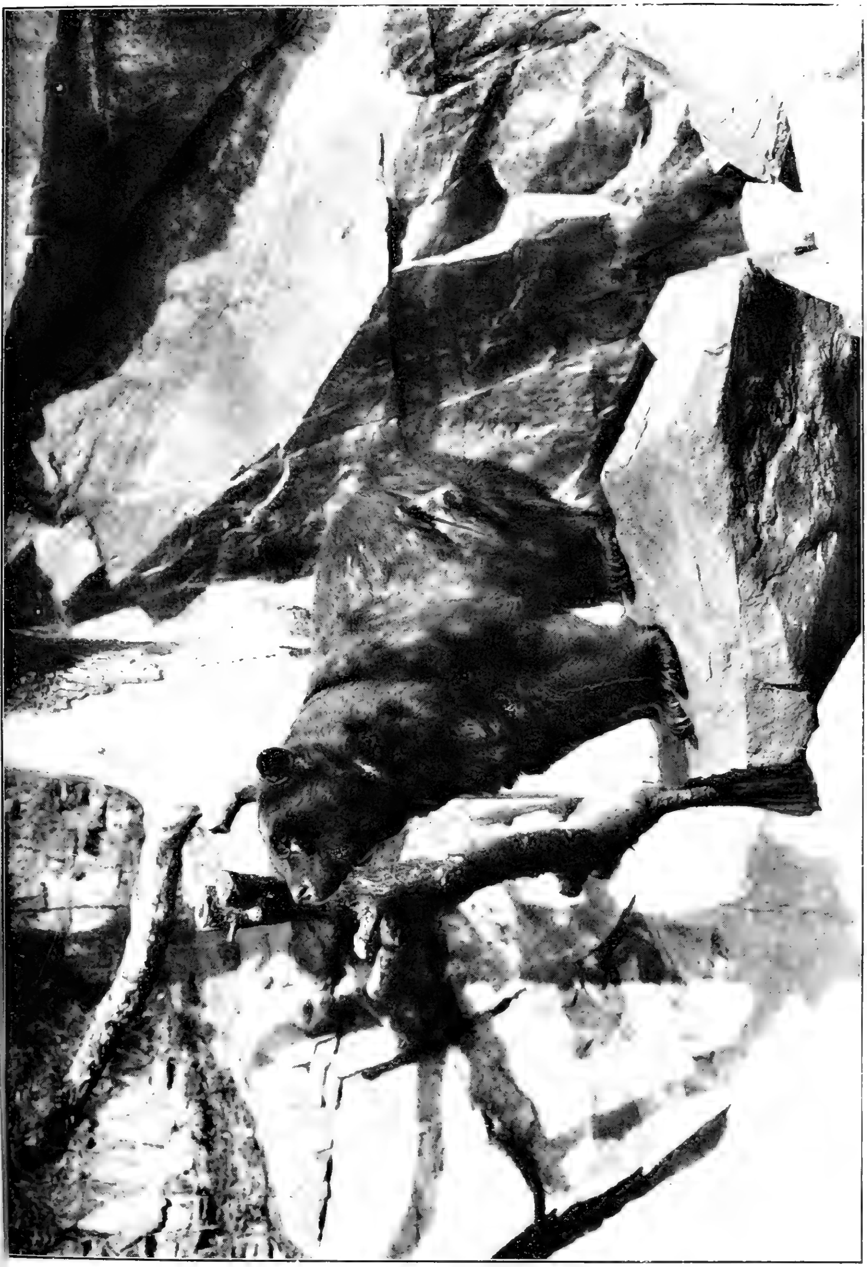
Maj. Charles A. P. Hatfield, U. S. A., Puerto Principe, Cuba, on behalf of his daughter, Miss Helen Hatfield, two jutia-conga and one sandhill crane.

The advent of these specimens and of others from domestic sources has taxed the park very severely to supply the necessary quarters. In several preceding reports attention has been drawn to the fact that there is not at present in the park any adequate housing provided for birds, reptiles, or small mammals. The larger cats are well housed, but for other classes the accommodations are insufficient. Animals from widely different regions, accustomed to different surroundings, temperature, and protection, are crowded together in a single building with the same conditions of heating, lighting, ventilation, and shelter. While the park has the nucleus of an excellent collection of aquatic birds, there are no suitable quarters for them during winter and they are then deprived of the proper bathing facilities. In consequence of this the whole of the fine group of flamingoes received from Cuba was lost. The parrots and macaws are necessarily placed during winter on top of the other cages within the principal animal house. In this situation they are not properly protected and the mortality is consequently far above what it should be.

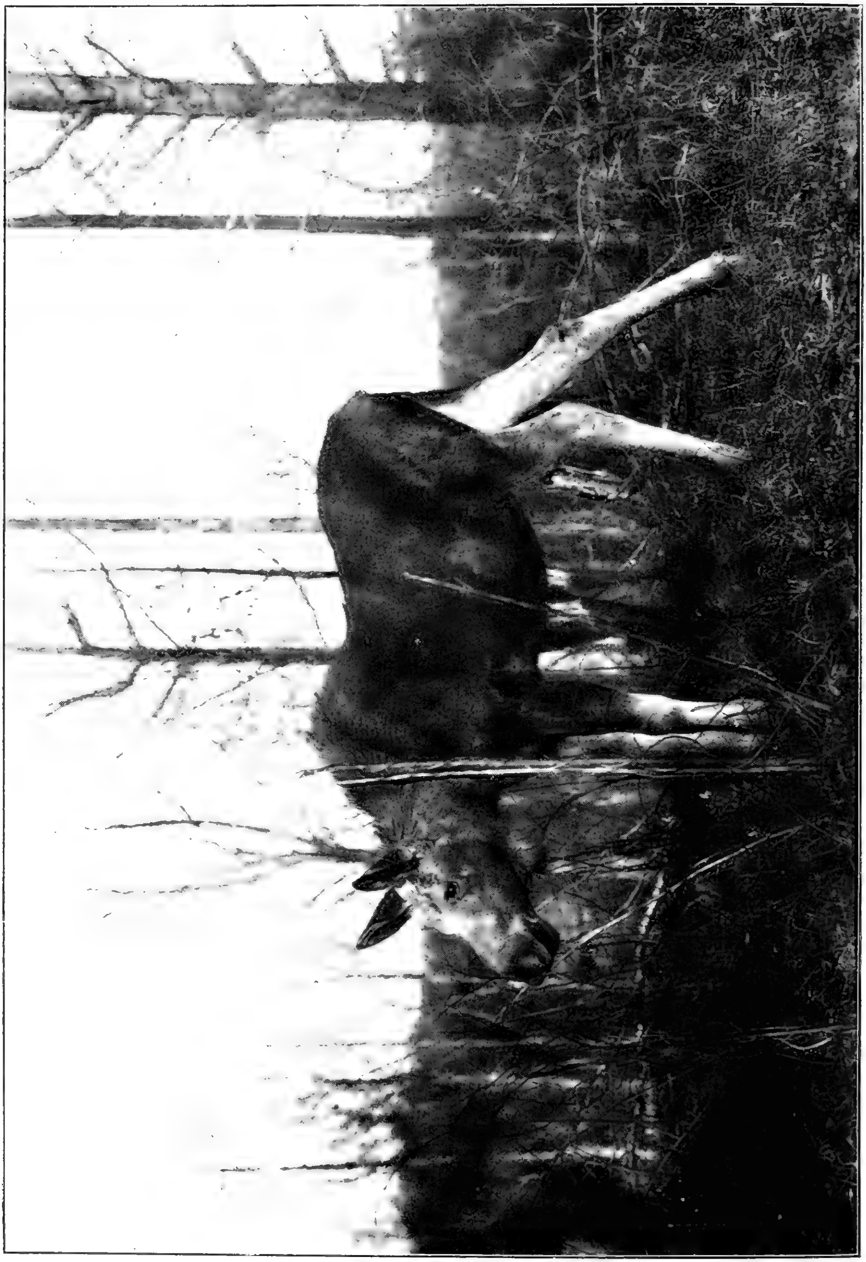
The reptiles of the park are in no better case. The rare and curious specimens of the giant tortoise from the Galapagos Islands are housed in an office room wholly unsuited for them, with but little sun and insufficiently ventilated. Many visitors never see these strange and remarkable animals. The alligators are unreasonably crowded, and often injure each other in consequence. There being no room for tanks for other amphibious creatures, no attempt has been made to obtain the rapidly disappearing American crocodile or any of the large sea turtles of our coast. The collection of snakes is very badly crowded, one case sufficing for the great tree snakes—pythons, boas, and anacondas being crowded together in a manner that is uncomfortable for the animals and confusing to the public. All this is in marked contrast to the practice in the best zoological gardens elsewhere, which have reptile houses with glass cages, in which the animals can receive proper attention and have earth, water, and sunlight. The recently constructed reptile house at the New York Zoological Park cost $48,000, and is one of the chief attractions of the place.

The small mammals are so inadequately housed that visitors have complained of certain cases. Many of them have no outside yards, and nothing can be done toward providing them with natural surroundings or with secluded breeding cages. In this the cardinal principle that was in view at the establishment of the park is violated,

PLATE IV.



Bear in Zoological Park.



MOOSE IN ZOOLOGICAL PARK.

and something must be done to remedy these defects if any proper results are expected.

Immediate steps should be taken for the erection of a suitable bird and reptile house, as well as a house for small mammals, these being the most important needs of the park at the present time.

Some attempts have been made during the year to collect rare and valuable American animals by organizing special expeditions on a limited scale.

The great Kodiak bear of Alaska, of which mention has been made in former reports, is especially desired, not only because of its great size, but also because it is rapidly disappearing. Persistent but fruitless efforts have been made to procure this animal through the various fur-trading agencies that have posts in the country it inhabits. It was finally determined to send out Mr. Elwood Hofer, a well-known guide and hunter of the Yellowstone Park, who has served the Smithsonian well on many occasions. Mr. Hofer went to the Alaskan coast and Kodiak Island in April, but he did not succeed in capturing any bears nor even in taking cubs. Mr. Hofer was also commissioned to procure other Alaskan animals. The extent of country over which he was obliged to travel and the exingencies of transportation did not permit him to do much in this way. His total collections amounted to a grizzly bear cub, three black bear cubs, a young porcupine, and some ground squirrels. None of these, with the possible exception of the grizzly bear cub, whose specific characters have not yet been determined, are characteristic of Alaska, and could have been readily procured much nearer to the park. The expedition must be considered as a failure, owing to the difficulty of carrying on extended operations in that country and the scarcity of the animals.

Another animal that has been especially desired is the mountain sheep. Several attempts have previously been made to obtain specimens of this animal by offering definite prices to hunters. These have been unsuccessful, probably because the men have not been able to procure the necessary outfit and supplies for a long and arduous expedition. Finally a contract was made with Mr. C. S. Jones to make a special expedition for the purpose. Through the intervention of Senator Wolcott the governor of Colorado kindly accorded permission to collect in that State for the United States Government. It was hoped to procure three pairs of animals, but only two young lambs, both males, were captured, and these have since died.

An attempt was made to collect the California condor, the largest flying bird in North America, now rapidly becoming extinct. The park has procured one young specimen of this fine bird by purchase.

The aquarium has been an object of considerable interest to visitors during the year. Acknowledgment should be made of the courtesy shown by Mr. J. E. Jones, the director of the public aquarium at Battery Park, New York City, who has greatly added to the interest of the collection here by exchange of valuable specimens, among which were several of the beautifully colored tropical fishes from the Bermudas. Considerable attention has been paid during the year to the preparation of plans and estimates for a new aquarium building suitable for the permanent installation of an attractive exhibit, but Congress has made no appropriation for the purpose.

Besides the service rendered by the Park to the schools, which was commented on in a previous report, the value of its collections has received recognition from another source. Well-known illustrators, including Messrs. Charles R. Knight, J. M. Gleeson, and L. A. Fuertes, have worked here during the year for considerable periods, and some of Mr. Ernest Seton-Thompson's charming pictures are based on studies made in the park.

Of the more important photographic work may be mentioned that of Mr. A. Radclyffe Dugmore, the author of "Bird Homes," whose picture of a beaver is shown herewith, and that of Mr. E. F. Keller, of New York City, whose photographs of mule deer, bear, moose, and antelope are also reproduced.

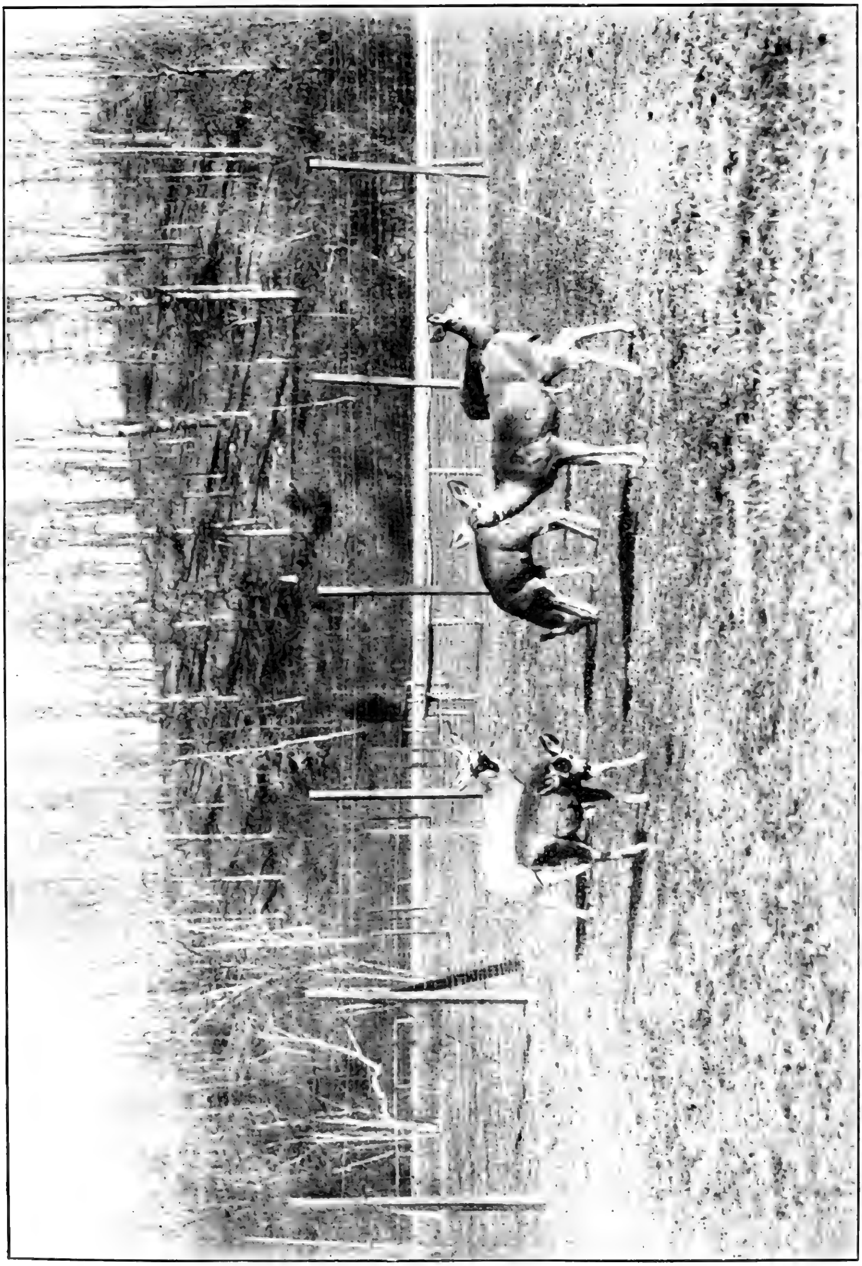
Under the unfavorable conditions that prevail in the park as to winter quarters, a low death rate can not be expected. The deaths during the year have reached 150, of which 87 were birds and reptiles. Among the more important losses are those of the Virginia deer already mentioned, a buffalo cow that died from some defect of nutrition, three antelopes, a mule deer, three black bears, and a cinnamon bear. A number of raccoons escaped from their inclosure.

From time to time surplus animals have been exchanged with other gardens or with dealers.

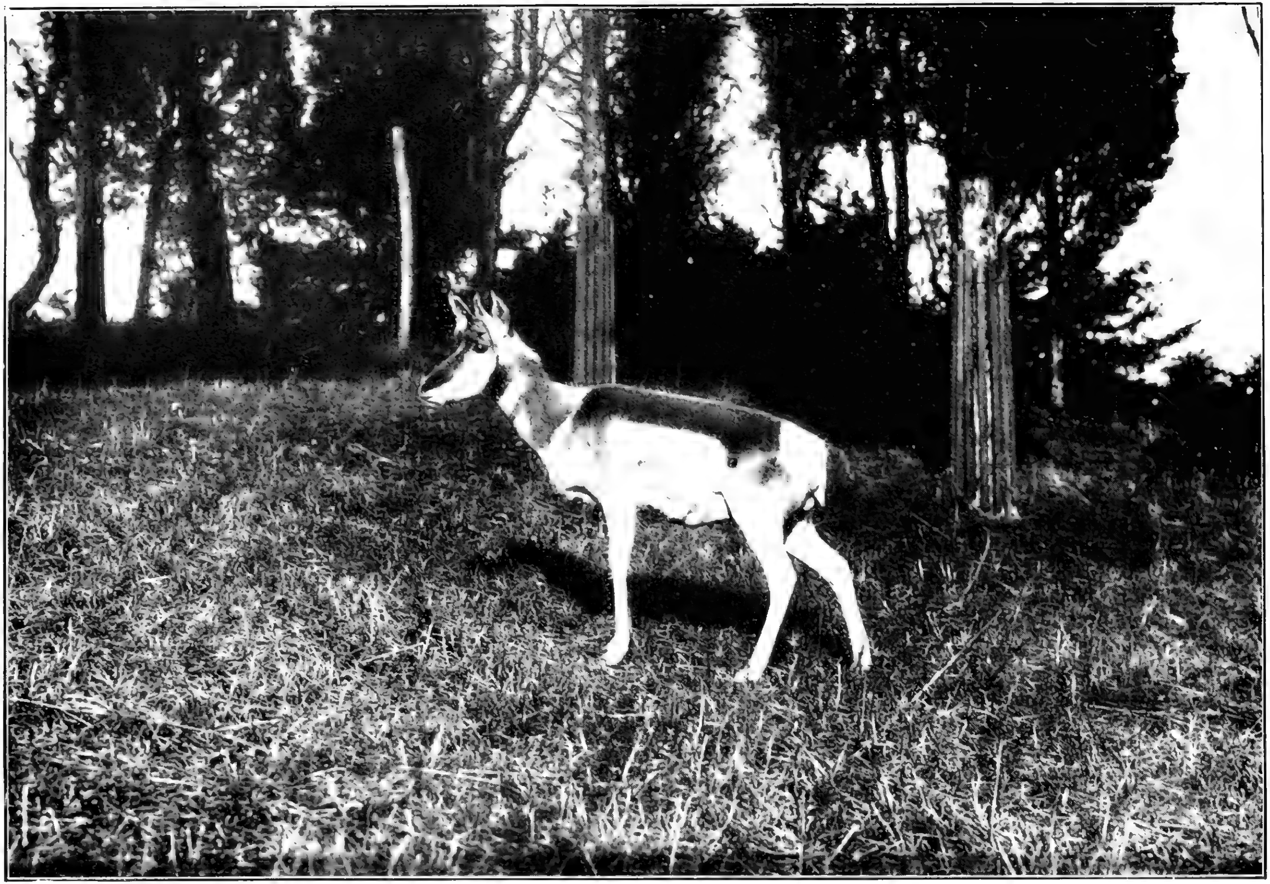
There are appended hereto a complete list of the animals in the park at the close of the fiscal year and a list of accessions from various sources.

Animals in the National Zoological Park, June 30, 1900.

Name.	Number.
MAMMALS.	
North American species.	
American bison (*Bison americanus*)	10
Prong-horn antelope (*Antilocapra americana*)	2
Virginia deer (*Odocoileus virginianus*)	7
Mule deer (*Odocoileus macrotis*)	4
American elk (*Cervus canadensis*)	21
Woodland caribou (*Rangifer caribou*)	1
Moose (*Alces americanus*)	2
Collared peccary (*Dicotyles tajaçu*)	2
Ocelot (*Felis pardalis*)	2
Puma (*Felis concolor*)	2
Spotted lynx (*Lynx rufus maculatus*)	3
Gray wolf (*Canis lupus griseo-albus*)	5
Black wolf (*Canis lupus griseo-albus*)	3
Coyote (*Canis latrans*)	9
Red fox (*Vulpes pennsylvanicus*)	7
Arctic fox (*Vulpes lagopus*)	11
Swift fox (*Vulpes velox*)	2
Gray fox (*Urocyon cinereo-argenteus*)	1
North American otter (*Lutra hudsonica*)	1
American badger (*Taxidea americana*)	2
Kinkajou (*Cercoleptes caudivolvulus*)	1
Common skunk (*Mephitis mephitica*)	1
American civet cat (*Bassariscus astuta*)	1
Gray coatimundi (*Nasua narica*)	1
Raccoon (*Procyon lotor*)	18
Black bear (*Ursus americanus*)	3
Cinnamon bear (*Ursus americanus*)	1
Grizzly bear (*Ursus horribilis*)	2
Polar bear (*Thalarctos maritimus*)	1
California sea lion (*Zalophus californianus*	4
Harbor seal (*Phoca vitulina*)	2
Common pocket gopher (*Geomys bursarius*)	2
California pocket gopher (*Thomomys bottæ*)	2
American beaver (*Castor fiber*)	5
Hutia-conga (*Capromys pilorides*)	5
Woodchuck (*Arctomys monax*)	2
Prairie dog (*Cynomys ludovicianus*)	63
MAMMALS—continued.	
North American species—Continued.	
Fox squirrel (*Sciurus niger*)	9
Gray squirrel (*Sciurus carolinensis*)	29
Mountain chipmunk (*Eutamias speciosus*)	18
Thirteen-lined spermophile (*Spermophilus tridecimlineatus*)	13
Beechey's ground squirrel (*Spermophilus beecheyi*)	1
Yellow-headed ground squirrel (*Spermophilus brevicaudus*)	20
Antelope chipmunk (*Spermophilus leucurus*)	2
Canada porcupine (*Erethizon dorsatus*)	4
Mexican agouti (*Dasyprocta mexicana*)	2
Northern varying hare (*Lepus americanus*)	9
Rocky Mountain varying hare (*Lepus americanus bairdi*)	1
Peba armadillo (*Tatusia novemcincta*)	3
Opossum (*Didelphys virginiana*)	1
Domesticated and foreign species.	
Macaque monkey (*Macacus cynomolgus*)	8
Bonnet monkey (*Macacus sinicus*)	1
Moor macaque (*Macacus maurus*)	1
Green monkey (*Cercopithecus callitrichus*)	1
Black ape (*Cynopithecus niger*)	1
Red-faced spider monkey (*Ateles paniscus*)	1
Black spider monkey (*Ateles ater*)	1
Gray spider monkey (*Ateles grisescens*)	1
Apella monkey (*Cebus apella*)	2
Capuchin (*Cebus capucinus*)	4
Azara's douroucouli (*Nyctipithecus azaræ*)	1
Lion (*Felis leo*)	8
Tiger (*Felis tigris*)	2
Leopard (*Felis pardus*)	2
Spotted hyena (*Hyæna crocuta*)	1
Wolf hound	2
St. Bernard dog	1
Pointer	1
Chesapeake Bay dog	1
Bedlington terrier	1



MULE DEER IN ZOOLOGICAL PARK.



ANTELOPE IN ZOOLOGICAL PARK.

Animals in the National Zoological Park, June 30, 1900—Continued.

Name.	Number.
MAMMALS—continued.	
Domesticated and foreign species—Cont'd.	
Smooth-coated fox terrier	3
Wire-haired fox terrier	1
Brown French poodle	1
Eskimo dog	3
Mongoose (*Herpestes mungo*)	1
Tayra (*Galictis barbara*)	1
Red coati-mundi (*Nasua rufa*)	2
Crab-eating raccoon (*Procyon cancrivora*)	2
Sun bear (*Ursus malayanus*)	1
Sloth bear (*Melursus labiatus*)	1
Indian fruit bat (*Pteropus medius*)	2
Wild boar (*Sus scrofa*)	2
Solid-hoofed pig (*Sus scrofa var.*)	1
White-lipped peccary (*Dicotyles labiatus*)	2
Zebu (*Bos indicus*)	9
Yak (*Poephagus grunniens*)	1
Barbary sheep (*Ovis tragelaphus*)	1
Common goat (*Capra hircus*)	9
Cashmere goat (*Capra hircus*)	4
Angora goat (*Capra hircus*)	3
Nylghai (*Boselaphus tragocamelus*)	2
Indian antelope (*Antilope cervicapra*)	1
Sambur deer (*Cervus aristotelis*)	1
Philippine deer (*Cervusphilippinus*)	1
Fallow deer (*Dama vulgaris*)	1
Common camel (*Camelus dromedarius*)	3
Llama (*Auchenia glama*)	4
South American tapir (*Tapirus americanus*)	1
Baird's tapir (*Elasmognathus bairdi*)	1
Indian elephant (*Elephas indicus*)	1
Crested agouti (*Dasyprocta cristata*)	3
Hairy-rumped agouti (*Dasyprocta prymnolopha*)	1
Azara's agouti (*Dasyprocta azaræ*)	2
Acouchy (*Dasyprocta acouchy*)	3
Golden agouti (*Dasyprocta aguti*)	2
Albino rat (*Mus rattus*)	5
Crested porcupine (*Hystrix cristata*)	3
Guinea pig (*Cavia porcellus*)	14
English rabbit (*Lepus cuniculus*)	15
Six-banded armadillo (*Dasypus sexcinctus*)	1
Gray kangaroo (*Macropus sp.*)	3
Bennett's red-necked wallaby (*Macropus ruficollis bennetti*)	1
Red kangaroo (*Macropus rufus*)	1
Brush-tailed rock kangaroo (*Petrogale penicillata*)	1
BIRDS.	
Clarke's nutcracker (*Nucifraga columbiana*)	2
Road runner (*Geococcyx californianus*)	8

Name.	Number.
BIRDS—continued.	
Sulphur-crested cockatoo (*Cacatua galerita*)	2
Leadbeater's cockatoo (*Cacatua leadbeateri*)	1
Roseate cockatoo (*Cacatua roseicapilla*)	5
Yellow and blue macaw (*Ara ararauna*)	2
Red and yellow and blue macaw (*Ara macao*)	3
Green paroquet (*Conurus sp.*)	2
Carolina paroquet (*Conurus carolinensis*)	3
Yellow-naped amazon (*Amazona auropalliata*)	1
White-fronted amazon (*Amazona leucocephala*)	4
Festive amazon (*Amazona festiva*)	1
Levaillant's amazon (*Amazona levaillanti*)	3
Mealy amazon (*Amazona farinosa*)	1
Gray parrot (*Psittacus crithacus*)	3
Great horned owl (*Bubo virginianus*	10
Barred owl (*Syrnium nebulosum*)	4
Bald eagle (*Haliæetus leucocephalus*)	6
Harpy eagle (*Thrasaëtus harpyia*)	1
Golden eagle (*Aquila chrysaëtos*)	1
Red-tailed hawk (*Buteo borealis*)	6
Broad-winged hawk (*Buteo pennsylvanicus*)	1
Sparrow hawk (*Falco sparverius*)	1
California condor (*Pseudogryphus californianus*)	1
Turkey vulture (*Cathartes aura*)	5
Ring dove (*Columba palumbus*)	7
Chachalaca (*Ortalis vetula maccallii*)	3
Guan (*Penelope sp.*)	3
Crested curassow (*Crax alector*)	1
Lesser razor-billed curassow (*Mitua tomentosa*)	1
Wild turkey (*Meleagris gallopavo*)	2
Pea fowl (*Pavo cristatus*)	34
Valley partridge (*Callipepla californica vallicola*)	6
Mountain partridge (*Oreortyx pictus*)	4
Sandhill crane (*Grus mexicana*)	2
Whooping crane (*Grus americana*)	1
Green heron (*Ardea virescens*)	3
Little blue heron (*Ardea cærulea*)	1
Great blue heron (*Ardea herodias*)	4
Black-crowned night heron (*Nycticorax nycticorax nævius*)	2
Scarlet ibis (*Guara rubra*)	2
Boatbill (*Cancroma cochlearia*)	1
Whistling swan (*Olor columbianus*)	5
Mute swan (*Cygnus gibbus*)	5
Brant (*Branta bernicla*)	3
Canada goose (*Branta canadensis*)	3

Animals in the National Zoological Park, June 30, 1900—Continued.

Name.	Number.
BIRDS—continued.	
Hutchins's goose (*Branta canadensis hutchinsii*)	1
Chinese goose (*Anser cygnoides*)	2
Mandarin duck (*Dendronessa galericulata*)	16
Pintail (*Dafila acuta*)	1
Pekin duck (*Anas sp.*)	4
Mallard duck (*Anas boschas*)	2
Common duck (*Anas boschas*)	2
American tree duck (*Dendrocygna discolor*)	1
American white pelican (*Pelecanus erythrorhynchos*)	8
Brown pelican (*Pelecanus fuscus*)	5
Florida cormorant (*Phalacrocorax dilophus floridanus*)	3
Snake bird (*Anhinga anhinga*)	3
Gannet (*Sula bassana*)	2
American herring gull (*Larus argentatus smithsonianus*)	1
Common rhea (*Rhea americana*)	1
Cassowary (*Casuarius galeatus*)	2
REPTILES.	
Alligator (*Alligator mississippiensis*)	28
Painted turtle (*Chrysemys picta*)	6
Musk turtle (*Aromochelys odorata*)	2
Mud turtle (*Cinosternum pennsylvanicum*)	5
Terrapin (*Pseudemys sp.*)	1
Gopher turtle (*Xerobates polyphemus*)	1
Tortoise (*Cistudo carolina*)	2
Duncan Island tortoise (*Testudo ephippium*)	2
Albemarle Island tortoise (*Testudo vicina*)	2
REPTILES—continued.	
Banded basilisk (*Basiliscus vittatus*)	1
Iguana (*Iguana sp.*)	1
Mexican comb-lizard (*Ctenosaura teres*)	6
Bailey's lizard (*Crotaphytus baileyi*)	1
Alligator lizard (*Sceloporus sp.*)	1
Skink-tailed lizard (*Gerrhonotus scincicauda*)	1
Gila monster (*Heloderma suspectum*)	5
Diamond rattlesnake (*Crotalus adamanteus*)	2
Banded rattlesnake (*Crotalus horridus*)	4
Copperhead (*Ancistrodon contortrix*)	3
Water moccasin (*Ancistrodon piscivorus*)	2
Indian python (*Python molurus*)	1
West African python (*Python sebæ*)	1
Common boa (*Boa constrictor*)	25
Yellow tree-boa (*Epicrates inornatus*)	2
Anaconda (*Eunectes murinus*)	2
Scarlet snake (*Cemophora coccinea*)	1
Bull snake (*Pituophis sayi*)	3
Pine snake (*Pituophis melanoleucus*)	1
Black snake (*Bascanium constrictor*)	2
Coach-whip snake (*Bascanium flagelliforme*)	1
King snake (*Ophibolus getulus*)	3
Mountain black snake (*Coluber obsoletus*)	1
Garter snake (*Eutænia sirtalis*)	3
Water snake (*Natrix sipedon*)	5
Gopher snake (*Spilotes corais couperii*)	3

List of accessions for the fiscal year ending June 30, 1900.

ANIMALS PRESENTED.

Name.	Donor.	Number of specimens.
Macaque monkey	Dr. W. M. Nihiser, Keedysville, Md	1
Moor macaque	Lieut. Wm. A. Lieber, U. S. A	1
Black ape	do	1
Apella monkey	Dr. J. Paes de Carvalho, Para, Brazil	1
Red-faced spider monkey	do	1
Gray spider monkey	Edward Somborn, Washington, D. C	1
Capuchin	August Schwartz, Washington, D. C	1
Azara's douroucouli	Dr. J. Paes de Carvalho, Para, Brazil	1
Ocelot	do	1
Red fox	Benj. Miller, Washington, D. C	1
Do	Mrs. H. Cobb, Washington, D. C	1
Do	Donor unknown	1
Red coati-mundi	Dr. J. Paes de Carvalho, Para, Brazil	1
Raccoon	W. M. Keeler, Washington, D. C	2
Do	Miss E. Scholl, Washington, D. C	1

List of accessions for the fiscal year ending June 30, 1900—Continued.

ANIMALS PRESENTED—Continued.

Name.	Donor.	Number of specimens.
Crab-eating raccoon	Lieut. Commander W. H. H. Southerland, U. S. N	2
Black bear	A. B. Suit, Suitland, Md	1
Baird's tapir	Lieut. Roger Welles, jr., U. S. N	1
Virginia deer	Gridiron Club, Washington, D. C	1
Philippine deer	Capt. George F. Chase, U. S. A	1
White-lipped peccary	Alfred Benitz, Calchaqui, Argentine Republic	1
Gray squirrel	G. S. Rosson, Washington, D. C	1
Do	Mrs. A. J. Marble, Berkeley Springs, W. Va	1
Do	—. —. Fred, Washington, D. C	1
Do	Miss Robb, Washington, D. C	1
Do	Mrs. F. C. Beig, Washington, D. C	1
Do	Donor unknown	1
Woodchuck	George Hellen, Washington, D. C	1
Jutia-conga	Gen. Clemente Dantin y Feliz, Bolondron, Cuba	2
Do	Miss Helen Hatfield, Puerto Principe, Cuba	2
Golden agouti	Dr. J. Paes de Carvalho, Para, Brazil	2
Crested agouti	Crew of U. S. S. Dolphin	1
Guinea pig	Wilber L. Wright, jr., Washington, D. C	2
English rabbit	J. W. Somerville, Washington, D. C	6
Do	R. L. McGuire, Washington, D. C	2
Do	Miss India King, Washington, D. C	1
Do	Miss Ada B. Gayer, Washington, D. C	1
Do	N. E. Besson, Washington, D. C	4
Do	Stanley Coville, Washington, D. C	1
Opossum	Dr. C. W. Montgomery, Washington, D. C	1
Road runner	Henry Bishop, Baltimore, Md	6
Roseate cockatoo	Mrs. B. W. King, Takoma Park, D. C	1
Red and yellow and blue macaw.	Dr. J. Paes de Carvalho, Para, Brazil	1
Red-fronted amazon	Miss de Carvalho, Washington, D. C	1
Do	Mrs. G. N. Lieber, Washington, D. C	1
Great horned owl	Julius Schneaholz, Washington, D. C	1
Screech owl	W. H. Gill, Washington, D. C	1
Red-tailed hawk	Dr. W. H. Seaman, Washington, D. C	1
Do	R. B. Leathers, Washington, D. C	1
Do	J. E. Babcock, Washington, D. C	1
Do	Thomas A. Cox, jr., Cullowhee, N. C	1
Turkey vulture	Gridiron Club, Washington, D. C	1
Wild turkey	Louis Krafft, Alexandria, Va	4
Sandhill crane	Miss Helen Hatfield, Puerto Principe, Cuba	1
Boatbill	Dr. J. Paes de Carvalho, Para, Brazil	1
Scarlet ibis	do	2
American flamingo	Brig. Gen. Jas. H. Wilson, U. S. V	9
American black-backed goose.	Dr. J. Paes de Carvalho, Para, Brazil	2
American tree duck	do	2
Mandarin duck	Mrs. Gardiner G. Hubbard, Washington, D. C	3
Do	Donor unknown	1
Alligator	Eugene Letcher, Washington, D. C	1
Do	Elmer Bateman, Washington, D. C	1
Do	Miss Mary Brewster, Washington, D. C	1
Do	Mrs. A. L. Barber, Washington, D. C	2
Do	H. Smith, Washington, D. C	1

List of accessions for the fiscal year ending June 30, 1900—Continued.

ANIMALS PRESENTED—Continued.

Name.	Donor.	Number of specimens.
Alligator	Miss Norris, Washington, D. C	2
Do	E. W. Roberts, Baltimore, Md	2
Iguana	Henry Bishop, Baltimore, Md	1
Banded rattlesnake	C. N. Uslin, Princess Anne County, Va	1
Copperhead	B. T. Galloway, Washington, D. C	1
Common boa	Dr. J. Paes de Carvalho, Para, Brazil	1
Anaconda	do	1
Black snake	H. H. Dove, Washington, D. C	1
Do	Amals Harris, Washington, D. C	1
Coachwhip	A. M. Nicholson, Orlando, Fla	3
King snake	do	1
Pilot snake	G. S. Miller, jr., Washington, D. C	1
Hog-nosed snake	William F. Seal, Delair, N. J	1
Garter snake	Dr. E. R. Hodge, Washington, D. C	1

ANIMALS LENT.

Name.	Donor.	Number of specimens.
Macaque monkey	U. S. Marine Hospital	2
Do	W. M. Keeler, Washington, D. C	1
Pig-tail monkey	W. P. M. King, Washington, D. C	1
Java monkey	Lieut. T. F. Schley, U. S. A	1
Arctic fox	Byron Andrews, Washington, D. C	12
Raccoon	E. S. Schmid, Washington, D. C	4
Black bear	Admiral George Dewey, U. S. N	1
Do	T. M. Rudd, Washington, D. C	1
Common goat	R. J. Wynne, Washington, D. C	1
Do	E. S. Schmid, Washington, D. C	5
Canada porcupine	do	1
White-fronted amazon	R. G. Paine, Washington, D. C	1
Yellow-headed amazon	Mrs. L. Hopfenmaier, Washington, D. C	1
Yellow-naped amazon	Mrs. A. B. Williams, Washington, D. C	1
Green paroquet	Miss Clarke, Washington, D. C	1
Great horned owl	Edw. S. Schmid, Washington, D. C	1
Barred owl	do	1
Sparrow hawk	do	1
Red-tailed hawk	do	1
Common boa	R. G. Paine, Washington, D. C	4

ANIMALS RECEIVED IN EXCHANGE.

Name.	Donor.	Number of specimens.
Black wolf	Henry Bishop, Baltimore, Md	1
Raccoon	do	7
Do	E. S. Schmid, Washington, D. C	5
Polar bear	William Bartels, New York	1
Nylghai	do	1
Angora goat	Henry Bishop, Baltimore, Md	2
Wild boar	do	2
Collared peccary	William Bartels, New York	2
Roseate cockatoo	G. Sebille, Washington, D. C	5
White-fronted amazon	William Bartels, New York	6
European lapwing	G. Sebille, Washington, D. C	2
Gannet	Henry Bishop, Baltimore, Md	2
Common rhea	Carl Hagenbeck, Hamburg, Germany	1

Animals purchased and collected.

Macaque monkey (*Macacus sp.*)	4
Civet cat (*Bassariscus astuta*)	2
California sea lion (*Zalophus californianus*)	1
Woodland caribou (*Rangifer caribou*)	1
Moose (*Alces americanus*)	2
Fox squirrel (*Sciurus niger*)	14
Thirteen-lined spermophile (*Spermophilus tridecimlineatus*)	13
Prairie dog (*Cynomys ludovicianus*)	19
Canada porcupine (*Erethizon dorsatus*)	2
Northern varying hare (*Lepus americanus*)	7
Red-tailed hawk (*Buteo borealis*)	1
Turkey vulture (*Cathartes aura*)	2
California condor (*Pseudogryphus californianus*)	1
Great horned owl (*Bubo virginianus*)	2
Little blue heron (*Ardea cærulea*)	1
Whistling swan (*Olor columbianus*)	4
Brown pelican (*Pelecanus fuscus*)	5
Snake bird (*Anhinga anhinga*)	2
Mexican comb lizard (*Ctenosaura teres*)	12
Banded rattlesnake (*Crotalus horridus*)	4
Scarlet snake (*Cemophora coccinea*)	1
Pine snake (*Pituophis melanoleucus*)	2
Black snake (*Bascanium constrictor*)	1

Animals born in the National Zoological Park.

Gray wolf (*Canis lupus griseo-albus*)	5
Coyote (*Canis latrans*)	4
Buffalo (*Bison americanus*)	1
Zebu (*Bos indicus*)	3
Common goat (*Capra hircus*)	2
Angora goat (*Capra hircus*)	1
Cashmere goat (*Capra hircus*)	1
American elk (*Cervus canadensis*)	2
Virginia deer (*Odocoileus virginianus*)	2
Llama (*Auchenia glama*)	2
Gray squirrel (*Sciurus carolinensis*)	2
Prairie dog (*Cynomys ludovicianus*)	19
Canada porcupine (*Erethizon dorsatus*)	1
Gray kangaroo (*Macropus sp.*)	1
Peafowl (*Pavo cristatus*)	15
Pekin duck (*Anas sp.*)	1
Common boa (*Boa constrictor*)	62

Animals received from the Yellowstone Park.

American elk (*Cervus canadensis*)	9
Virginia deer (*Odocoileus virginianus*)	3
Mule deer (*Odocoileus macrotis*)	5

SUMMARY.

Animals on hand July 1, 1899	675
Accessions during the year	444
Total	1,119
Deduct losses (by exchange, death, and returning of animals)	280
On hand June 30, 1900	839

Respectfully submitted.

Frank Baker, *Superintendent.*

Mr. S. P. Langley,
Secretary Smithsonian Institution.

Beaver in National Zoological Park.

APPENDIX V.

REPORT OF THE WORK OF THE ASTROPHYSICAL OBSERVATORY FOR THE YEAR ENDING JUNE 30, 1900.

SIR: The kinds and amounts of the Observatory property are approximately as follows:

Buildings	$6,300.00
Apparatus	30,000.00
Library and records	5,400.00
Total	41,700.00

During the past year the acquisitions of property of the kinds just enumerated have been as follows:

(a) *Apparatus.*—Astronomical and physical apparatus has been purchased at an expenditure of $2,100.[1] The main separate items are an equatorial mounting for 8-inch telescope, with clock and with coelostat attachment; a 10-inch concave mirror of 75 centimeters focus, and a special tremor reducing support and magnetic shielding device designed for use with a new galvanometer of extraordinary sensitiveness. A 12-horse power motor with connection to the city electric service, for use in running the cooling plant, has been installed at a cost of $200.

(b) *Library and records.*—The usual periodicals have been continued, and additional photographic star and moon maps have been purchased, the total expenditure for these purposes being $200.

Total accessions of property, $2,500.

No alterations of consequence have been made in the Observatory buildings and grounds. The cost of repairs to buildings has aggregated $200.

Losses of property have been inconsiderable, from a monetary point of view, but I regret that a box of bolographs containing the originals of some of the illustrations of the forthcoming Volume I of the Annals was injured by water during my absence on the eclipse expedition, and the bolographs (about 20 in number) were much damaged. It is fortunate, however, that negatives of them are preserved.

THE WORK OF THE OBSERVATORY.

Two objects have principally occupied the Observatory staff during the past year—first, the publication of Annals of the Astrophysical Observatory, Volume I, and, second, the observation of the total solar eclipse of May 28, 1900. Considerable time was, however, devoted to the design and construction of the sensitive galvanometer, with magnetic shielding and steady support above alluded to.

It will be most convenient to describe the work of the year under three headings, as follows:

1. Publication.
2. Progress of the usual work of the Observatory.
3. Observation of the solar eclipse.

(1) *Publication.*—Volume I of Annals of the Astrophysical Observatory, now being issued, containing an account of the research on the infra-red solar spectrum and the

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[1] I here include only such apparatus as is of permanent value to the Observatory, and not such as served a merely temporary purpose in connection with the recent total solar eclipse.

mapping of the absorption lines in this region, and of subsidiary investigations connected with these, comprises nearly 300 pages, uniform in size with Smithsonian Contributions. It is illustrated by about thirty-five full-page or folded plates and numerous text figures. The text contains full descriptions of the apparatus and methods employed in mapping the infra-red solar spectrum by the aid of the bolometer, and gives as a result of research the positions in deviation and in wave length, as well as the relative intensities of over 700 absorption lines or bands between the visible limit of the red at A (0.76μ) and what is practically the limit of the solar spectrum for terrestrial purposes at 6μ.

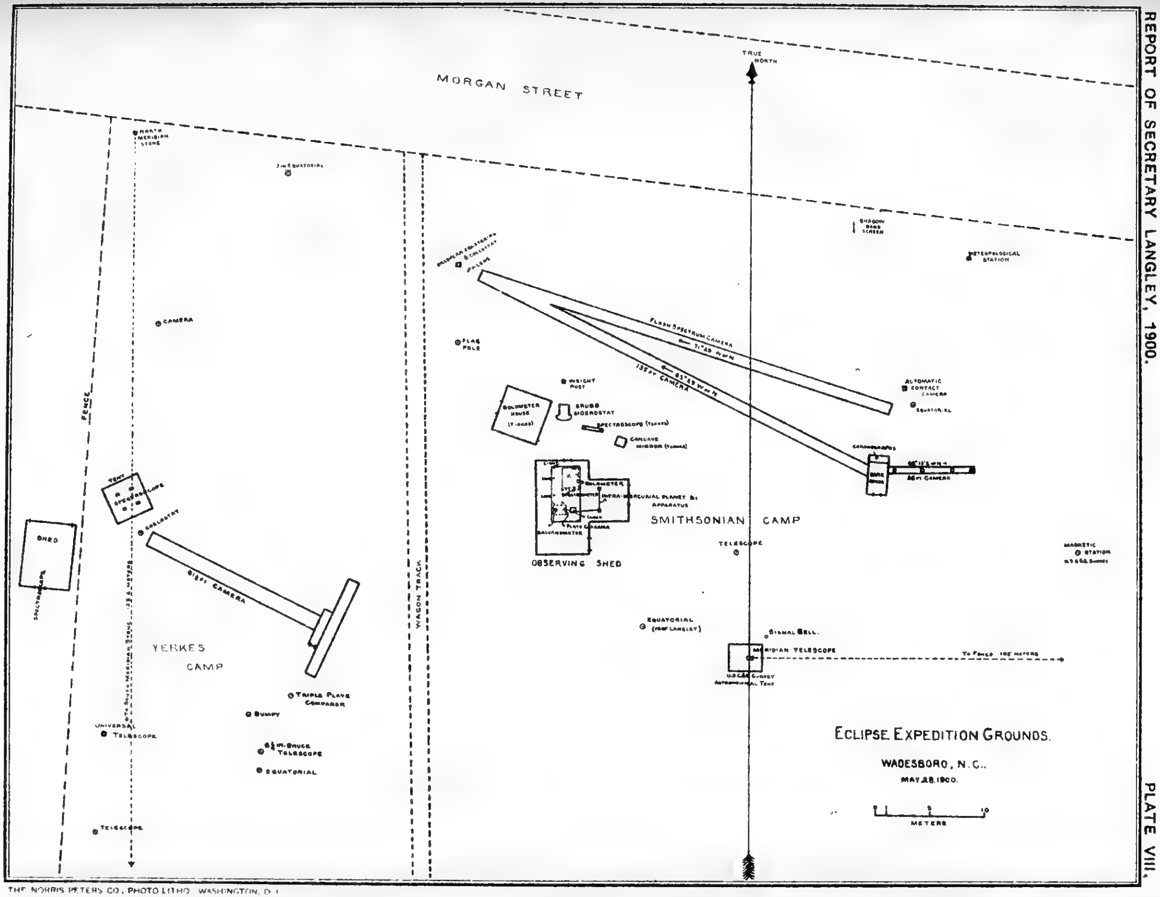
A chapter is devoted to a discussion of the seasonal and other variations in terrestrial absorption, which have been noted at many points in the infra-red spectrum. These variations, and especially those of a seasonal character, to which attention has been drawn in several of my earlier reports, form an extremely interesting and perhaps important feature of these studies.

It is greatly to be regretted that the very best photo-mechanical processes are inadequate to justly reproduce the bolographs, upon whose evidence the spectrum lines are determined, and this I fear will prove a still more serious hindrance to the publication of the photographic results of the eclipse expedition shortly to be described. This unavoidable inadequacy of representation is a very considerable obstacle to the satisfactory publication of astronomical and, to a lesser extent, other scientific results, in these days when the advance of science is increasingly connected with the interpretation of delicate photographic detail.

(2) *Progress of the usual work of the Observatory.*—The ordinary operations of the Observatory have been much restricted by the two special lines of work already alluded to, for it must be recalled that the present observing force consists of but two persons, so that the long preparations for the eclipse and the reading and rereading of the proof sheets of the Annals left little time for other work.

As mentioned in my last report, designs were then entertained for constructing a new galvanometer of the highest sensitiveness, with a support calculated to reduce to the lowest limits the earth tremors which are so prejudicial in the use of such sensitive instruments, and with a thorough system of magnetic shielding to enable the galvanometer to escape the fluctuations of the magnetic field. This apparatus has been finished, excepting the needle system of the galvanometer, and was tried in January of this year with a temporary needle system of only 1.9 milligrams weight. The result appears to be promising. As thus tried, with the galvanometer case partially exhausted and a time of swing of about three seconds, no fluctuations of the spot of light reflected from the galvanometer mirror exceeding 0.1^{mm} could be observed on the scale 2 meters distant. The system of support and the magnetic shielding appear, therefore, to be very perfect, and a few words describing them may be appropriate here.

System of support.—A massive pier rises through the basement room of the new laboratory to the level of the ground floor. Upon this is a four-legged table 8 feet high, whose top is a flat iron ring of about 500 pounds weight. Four iron cylinders are fastened upon the top of the ring, and in these float on mercury smaller iron cylinders supporting a second iron ring. From the floating ring descend three steel wires, each 15 feet long, passing through holes in the capstone of the pier and supporting a heavy cage of iron, in which is the galvanometer. The points of support are at the plane of the center of gravity of the iron cage, and also in the plane of the support of the galvanometer-needle system. Four dampers in glycerin baths prevent torsional vibration of the cage. Thus the whole is a combination of four methods of reducing the effects of earth tremors. First, a deep solid pier; second, a "rickety table," supporting a weight of 1,600 pounds; third, a mercury flotation of 1,000 pounds, whose center of gravity is below the mercury itself; fourth, a long "Julius three-wire suspension," supporting 700 pounds.

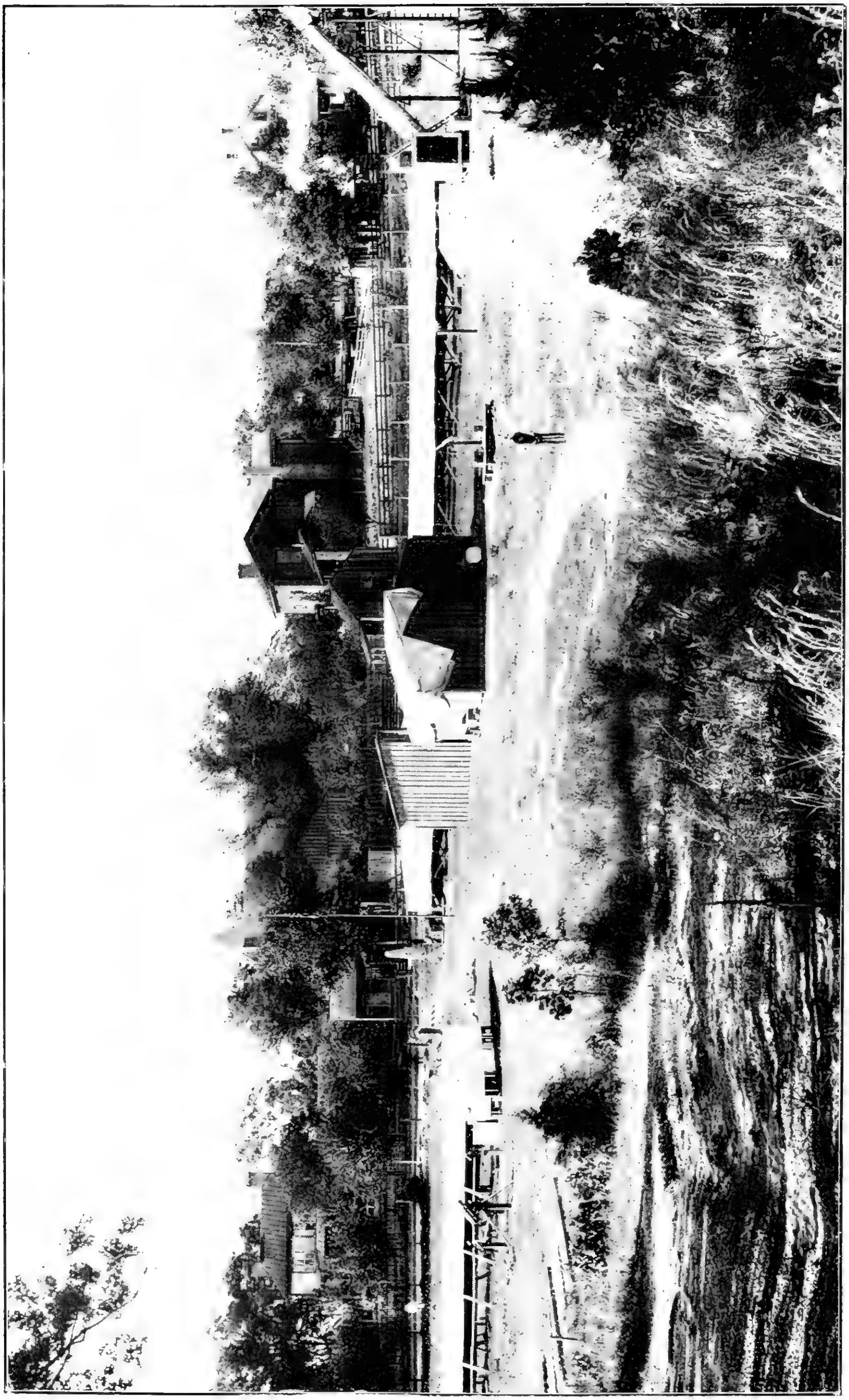


ECLIPSE EXPEDITION GROUNDS.

WADESBORO, N. C.

MAY 28, 1900.

THE NORRIS PETERS CO., PHOTO LITHO. WASHINGTON, D. C.



General View of Smithsonian Camp.

System of magnetic shielding.—Three magnetic shields are employed. The outer is a square iron box without top or bottom and of about 2 tons weight. Within this, and supported on the swinging iron cage, are two concentric iron cylinders, of which the inner is only 3 inches in diameter and immediately incloses the galvanometer. No side openings are made in the shields, the galvanometer being read by means of a spot of light reflected vertically through a glass in the capstone of the pier.

It will be noticed from this description that all observations will be conducted in the upper room, while the galvanometer itself is below the level of the ground in a room of very constant temperature. It is hoped shortly to continue work on this apparatus, and to provide the galvanometer with a needle system of great sensitiveness, which it is thought from the experiments already made may be used without prejudicial tremors in a vacuum and at ten seconds (single) vibration. If these expectations should be realized the useful or working sensitiveness of the new galvanometer will be several hundred times that customarily employed in mapping the infra-red solar spectrum, and a large new field of work will be practicable.

(3) *Observation of the solar eclipse.*—Considering the near approach of the path of totality of the total eclipse of May 28, 1900, you deemed it desirable for this Observatory to take part in the observation of this important astrophysical phenomenon, and this view having recommended itself to Congress, an appropriation of $4,000 was made immediately available for the purpose in February. The use of the special apparatus already belonging to the Observatory, the very generous offer by Prof. E. C. Pickering, the director of the Harvard College Observatory, of the loan of the new 12-inch lens of 135 feet focus belonging to the Harvard College Observatory, and of several other valuable pieces of optical apparatus, together with loans of a 5-inch lens of 38 feet focus by Princeton University, and of a 5-inch equatorial by the Naval Observatory, enabled the expedition to take larger proportions than this modest appropriation might otherwise have justified.

This apparatus with many other adjuncts was temporarily installed in Washington in the Smithsonian grounds, and placed in the position each piece would occupy in the actual eclipse. This was with the view of familiarizing the observers with them, by successive rehearsals, which went on with assiduous practice during two months before all was taken down for shipment to the proposed site.

Choice of site.—Three successive years of special observations had enabled the Weather Bureau to determine the relative chances of cloudiness at various points along the eclipse track, and from these results it appeared that the interior of the country was more favorably situated in this respect than those parts of the path lying near the coasts. Certain towns appeared more favorable than others, owing to local conditions, although such special results were less trustworthy than the broad indications already cited. However, as the Eastern stations were to have both a higher solar altitude and a longer duration of totality, and as personal inspection of the ground by me, together with a careful consideration of the Weather Bureau results, seemed to justify the selection, the town of Wadesboro, N. C., was approved by you in preference to stations more remote from Washington. The actual grounds occupied formed a nearly level plat of several acres extent, sheltered from the wind by knolls, buildings, and trees, but being almost the highest land thereabouts, and indeed about 600 feet above sea level. These grounds were freely offered by John Leak, esq., of Wadesboro. A shed and the necessary piers for instruments were erected in the latter part of April.

Plate No. VIII gives a ground plan of the Smithsonian camp, showing the canvas covers of the two 135-foot tubes, the sheds containing the bolometric apparatus and its accessories, and the photographic cameras for the 40-inch and 11-foot lenses, with numerous other pieces; and also on the left a portion of that of the Yerkes Observatory.

Plate No. IX gives a general view of the camp as finally occupied. The equipment of the Smithsonian expedition is shown at the right of the wagon track, while on the left is a portion of that of the Yerkes Observatory. The 135-foot horizontal telescope is under the canvas seen on the right. Its companion tube is hidden by it. On its left extremity is seen, though on a very diminished scale, the cœlostat mirror which "fed" it (this is shown on an enlarged scale in the next illustration), and also the box of the 6-inch aperture camera equatorially mounted. Immediately in front of the tube and cutting off a portion of the view are the sheds containing the apparatus for the bolometric study of the corona and that for the large cameras for the 11-foot and other lenses. The great Grubb siderostat and other pieces of apparatus are hidden from view by the sheds. On the right of the sheds and immediately in the foreground is the 5-inch achromatic loaned by the United States Naval Observatory. At the right hand extremity of the long tube is seen the photographic house, which serves equally for the 135-foot lens and for that of the 38-foot focus lens, which latter is in the tube inclined upward.

Nature of the observations.—The chief aim of the observations was the investigation of the corona, and of this especially the inner portions. This investigation was threefold—photographic, bolometric, and visual. In addition to these main objects there was included the photography of the sky near the sun for the discovery of possible unknown bodies, an attempt to photograph the "flash spectrum" with an automatic camera, and the observation of times of contact both by the ordinary visual methods and by photography.

Pieces of apparatus employed.—(a) Apparatus for photographic purposes: For the direct photography of the inner corona the 12-inch lens of 135 feet focus was used as a horizontal telescope in connection with a cœlostat carrying an 18-inch plane mirror. (Plate X.) Here are shown on a large scale the lens in question, the extremity of its canvas tube, and the cœlostat and equatorially mounted camera described in the preceding plate. It was also arranged to use with this lens just before second contact an objective prism forming a spectrum upon a plate moved each second by clockwork, and thus suited to catch the "flash spectrum," so called. This necessitated a second tube 135 feet long, inclined at about 8° to that used for the direct photographs of the corona. Both tubes were made of black canton flannel and were 42 inches square with diaphragms of progressively increasing size 10 feet apart. The two tubes were fastened to trestlework and were covered by long canvas A tents. Nearly 1,000 yards of canvas and flannel were thus made up. The direct tube ended in a small photographic house which had been prepared in sections and was transported from Washington. Plates 30 inches square were here exposed.

The direction of the long tubes was necessarily a matter of care, as they had to be placed beforehand where calculation showed the sun would be, and were incapable of adjustment.

Besides this great horizontal telescope, the 5-inch 38-foot lens was also used for obtaining inner coronal photographs. This lens was mounted upon a pole in such a way as to be in line with the sun from the east window of the photographic house at the moment of totality. A conical tube of white canvas, well blackened within, and 36 inches square at its lower end, ran from the house to the lens, but was not attached to the lens or its mounting. There being thus no provision for following the apparent motion of the sun with the lens, a suitable motion was given to the photographic plates by means of a water clock. With this instrument 11 by 14 inch plates were employed.

Upon the same instrument which carried the 18-inch mirror of the horizontal telescope (shown in Plate X) was mounted equatorially a 6-inch photographic lens of 7½ feet focus, provided with a conical tube, so that a considerable field was covered.[1]

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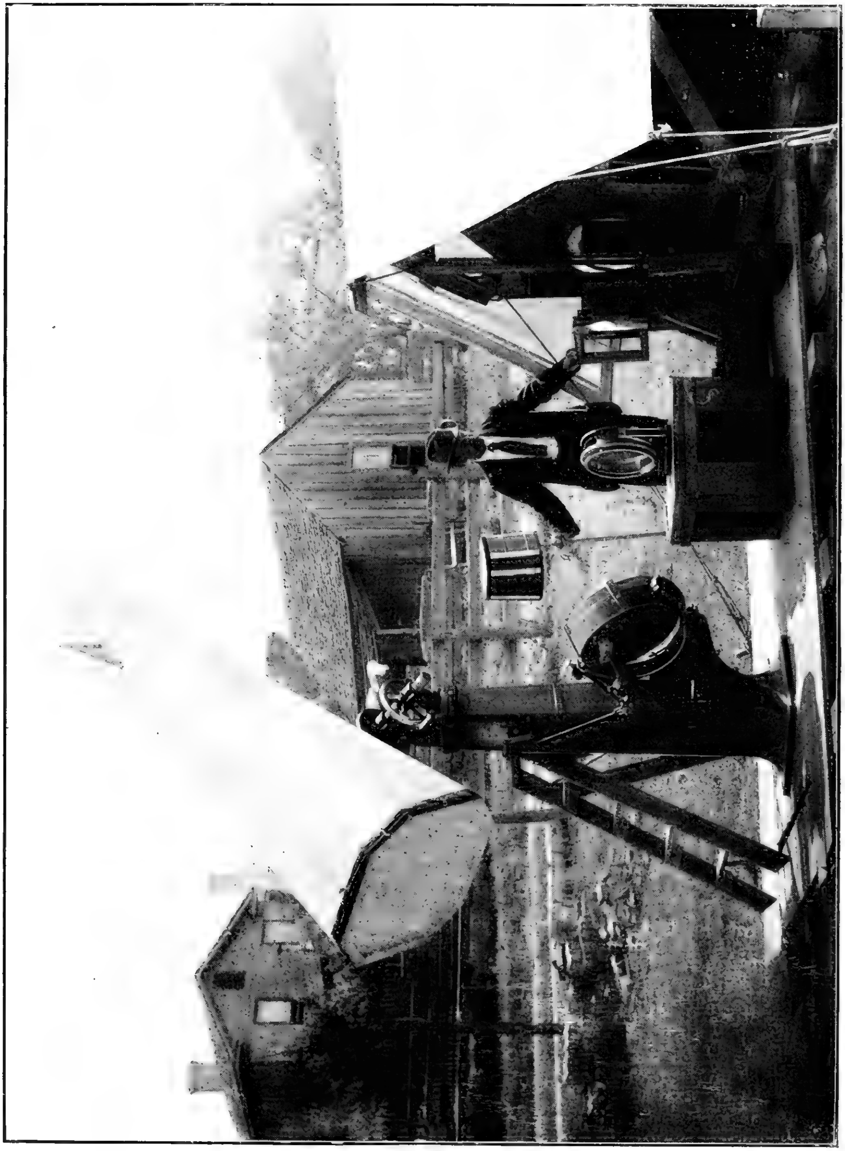
[1] The focal curve of this lens was determined and it was intended to use a nest of small plates so arranged as to be in focus over a large field. On the night before the eclipse, however, it was so warm that the wax used to fasten the plates softened repeatedly, and after several trials it was found necessary to use a flat plate, on which the focus was good for perhaps 6° from the center.



CŒLOSTAT WITH EQUATORIAL CAMERA AND SHOWING THE GREAT LENS AND PRISM.

INTRAMERCURIAL PLANET CAMERAS.

THE BOLOMETRIC APPARATUS.

A shade glass opaque to violet light was placed over this lens. The purpose of the shade glass was to enable a comparison to be made between the form of the outer corona as photographed with yellow and green light and as photographed with the complete coronal radiations by other lenses shortly to be described.

Within the eastern part of the shed there was mounted upon an improvised polar axis a collection of four cameras, quite ponderous in appearance, as indicated in Plate XI, but really not very heavy, and well provided as to moving gear by being connected with the very accurate spectrobolometer clock. These cameras were two similar pairs, one with short-focus, the other with long-focus lenses. The former were two landscape lenses of 4½ inches aperture and 40 inches focus, each provided with a 30-inch square plate. In front of one lens was placed a shade glass opaque to violet light. The two long-focus lenses were of 3 inches aperture and 11 feet focus, and were thus like those recommended in the Harvard College Observatory Circular No. 48 as most suitable for a photographic search for a possible intramercurial planet. The axes of these two cameras were inclined so that together they covered a space east and west of the sun about 12° by 28° in extent. Their fields were found to be so nearly flat as to make it undesirable to use a nest of plates arranged upon a curved surface, as recommended in the Harvard circular above alluded to, and each camera had a single plate 24 by 30 inches.

All the photographs with the seven lenses above described were taken upon Cramer double coated isochromatic plates of great rapidity.

An automatic camera, giving exposures from a break-circuit chronometer beating seconds, was provided for the purpose of securing the times of contacts. This camera had a 22-inch lens with pin-hole aperture, and the exposures were made upon very slow nonhalation celluloid plates 15 inches in diameter, rotated slightly after each exposure by an electrical escapement. One plate was provided for first contact, one for both second and third, and one for fourth contact. As no clockwork was applied to move this camera, the successive exposures made a spiral series of images of the sun, from the appearance of which the gradual encroaching of the moon could be observed.

(b) Apparatus for bolometric purposes: This consisted of a complete bolographic outfit, including not only the great Grubb siderostat with supplementary mirror, but also a double-walled chamber of nearly uniform temperature. The view of it is shown in Plate XII, and its purpose was to enable the total radiation of the inner corona to be observed, and in addition, if practicable, to determine the distribution of these radiations in the spectrum. The latter observation it was hoped would throw light on the composition of the corona, for it is well known that different substances and different temperatures have each its characteristic energy spectrum. A beam of light from the 17-inch mirror of the great siderostat, reflected due south into the shed, passed through a cat's-eye diaphragm whose aperture was controlled by the observer at the galvanometer, thence to a condensing mirror, which reflected the rays directly back to the focus at 1 meter distance, where was a slit 1 centimeter high and 1 millimeter wide. From the slit the rays were reflected out of the optic axis of the condensing mirror by two parallel plane mirrors, and fell upon a collimating mirror of 75 centimeters focus. Thence they were reflected upon a prism 8 inches in diameter, one of whose surfaces was silvered, so that the prism might be used either to refract or reflect the rays, according as the glass or silvered face was turned toward the collimator. From the prism the rays passed to an image-forming mirror, in the focus of which, at 75 centimeters distance, was the bolometer strip 1 centimeter high and 1 millimeter wide. The bolometer and galvanometer with their accessories were essentially as used for solar spectrum work in Washington, and while the optical train, with its seven reflections and small slit, greatly reduced the radiations, the sensitiveness of the bolometer was yet such that subsequent observations on the full moon gave a deflection of 85 divisions when the aperture of the diaphragm was but 17 centimeters square.

Nevertheless it was found that no "drift" or "wiggle" was noticed when the glass plate in front of the bolometer case was removed. Accordingly there was no plate in front of the bolometer at the time of the eclipse, and of course none was interposed during the observation just recorded.

The expedition was strengthened by the presence of Professor Hale, of Yerkes Observatory, who used a second beam from the 18-inch coelostat mirror, also driven by the great siderostat, in connection with bolometric apparatus for the purpose of observing if a difference in radiation could be detected between the coronal rifts and streamers.

(c) Apparatus for visual observations. Four visual telescopes were employed for observing the coronal structure and the times of contact. These were:

A 5-inch of about 6 feet focus (shown in Plate XIII), loaned by the United States Naval Observatory, having an equatorial stand and clock.

A 6-inch of 7½ feet focus with equatorial stand, but no clock.

A 3½-inch of 3½ feet focus with rough alt-azimuth stand.

A Coast Survey meridian transit instrument of about 2½ inches aperture and 2½ feet focus used as an alt-azimuth telescope to observe contacts.

THE PERSONNEL OF THE EXPEDITION.

The Director, Mr. S. P. Langley, Secretary of the Smithsonian Institution, observed with the 5-inch equatorial; and the other members of the expedition were assigned as follows:

Mr. C. G. Abbot, aid acting in charge, with Mr. C. E. Mendenhall to the bolometric apparatus.

Mr. T. W. Smillie, photographer of the National Museum (in general charge of photography, including the development of all plates), specially to the direct 135-foot focus camera.

Mr. F. E. Fowle, jr., junior assistant, to the 38-foot focus camera.

Mr. G. R. Putnam (detailed from the United States Coast and Geodetic Survey) to the determination of latitude and longitude, the observation of times of contact, and the direction of signals.

The Rev. Father Searle, C. S. P., together with Mr. Paul A. Draper and Mr. C. W. B. Smith, to the combination of four wide field cameras.

Mr. De Lancey Gill to the 6-inch photographic telescope and the objective prism.

Mr. R. C. Child to the 6-inch visual telescope, the electrical circuits of the chronograph, the prismatic camera, and the contact camera.

The Rev. Father Woodman, C. S. P., to the 3½-inch telescope.

Mr. A. Kramer, instrument maker, to the movements of the siderostat and 5-inch equatorial.

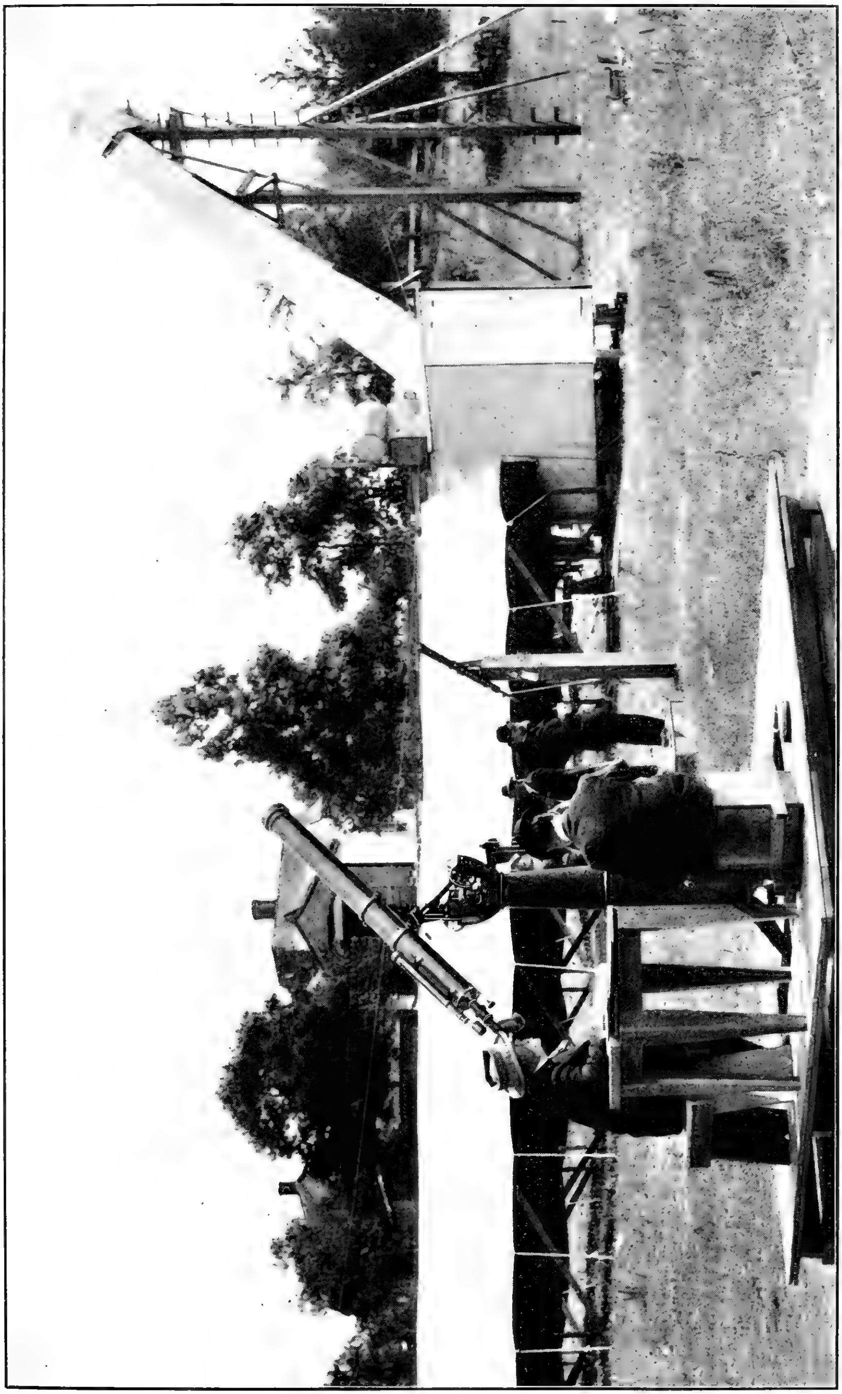
Besides these there volunteered for the day of the eclipse Mr. Little, of Wadesboro, and Mr. Hoxie, assigned, respectively, to strike signals and to record contacts for Mr. Putnam.

Prof. George E. Hale was connected, as already said, with the Smithsonian party, while at the same time in general charge of the Yerkes Observatory expedition, whose camp adjoined ours.

THE EXPEDITION.

After the preparation of the apparatus and the preliminary rehearsal for the eclipse on the Smithsonian grounds, a freight car was completely filled with the apparatus, and left Washington May 2.

The first four members of the expedition, Messrs. Abbot, Fowle, Kramer, and Smith, left Washington May 3, and were followed in a few days by two more, Messrs. Putnam and Draper, the former of whom, however, returned after determining the latitude and longitude and helping to adjust several polar axes. Messrs. Smillie, Mendenhall, Child, and Gill reached Wadesboro May 16, and the other members of the party arrived about two days before the time of the eclipse. Pleasant accommo-



THE 5-INCH EQUATORIAL.

dations were found in the town, only about a quarter of a mile from camp, and the greatest courtesy was shown to the eclipse expedition at all times by the townspeople. A pleasant feature was the presence of large parties from Yerkes Observatory, Princeton Observatory, and from the British Astronomical Association. The days and—toward the last—a considerable portion of the nights were busily occupied in adjusting and trying the apparatus. On May 26 and 27 full rehearsals took place in preparation for the final event.

The day of the eclipse was cloudless and clearer than is usual in the Eastern States, though the sky was not exceptionally blue. All the programme was carried out successfully, except only that Professor Hale's bolometer suffered an accident which prevented him from obtaining bolometric evidence of rifts and streamers, but not from securing other interesting data.

After the eclipse the members of the expedition returned home in nearly the same order as they came, and the last members to leave reached Washington June 1.

THE RESULTS.

1. *With the 135-foot direct camera.*—Mr. Smillie secured five negatives during the eclipse, all good. Three others which he exposed after totality were of much less value, as was to be expected. The enormous scale of these photographs (the moon's disk measures 15⅝ inches in diameter), together with the excellent detail in the prominences and inner corona, make them most interesting.

Plates XIV[1] and XV[1] show, respectively, the south polar streamers and a group of prominences on the southwest limb. As remarked at an earlier page, it has proved impossible to adequately reproduce the delicate detail of the originals. In the two illustrations given the subjects are so marked that a still interesting result is shown even after the loss of the finer structure. But the equatorial coronal streamers, though in the original clearly shown to be finely subdivided, curiously curved and even recurved, interlocked and arched, are so delicate that it was hopeless to attempt their reproduction. Even contact prints fail to show their structure unless made on glass plates, and thus viewed by transmitted light.

Some, but I think not all the prominences, appear to be set each within its little coronal arch, and thus present the so-called "hooded" appearance which was noted in photographs of the Indian eclipse of 1898. I am quite sure, however, that this feature is much less marked than was then the case.

It would hardly seem possible that the directions of the curved equatorial streamers can be assigned to such a simple system of foci as has been sometimes supposed, for their arrangement appears to be complicated to the last degree. Nothing final can yet be said on this point pending a thorough examination, and this it is hoped will yield many interesting results.

2. *With the 135-foot prismatic camera.*—Nothing of value was secured with this instrument. The plate appears to have been exposed at successive intervals, but was completely fogged over, no spectrum appearing.

3. *With the 38-foot camera.*—Mr. Fowle obtained seven negatives during totality, all good. Others taken after third contact were of little value. What has been said as regards the results with the 135-foot camera applies very well here, except that not quite equal detail was secured, owing to the lesser power of the apparatus. Somewhat greater coronal extension was, however, obtained in the longer exposures, because of the greater focal ratio of the lens, and Plate XVI is given to illustrate this part of the corona.

4. *With the 6-inch photographic telescope.*—Mr. Gill obtained an excellent negative of eighty-two seconds' exposure, showing the longest extension of the coronal streams obtained with any of the instruments. It seems probable, however, that a somewhat better result would have been reached with a less exposure or a less aperture.

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[1] These are not enlarged, but are portions of the original focal images of over 15 inches diameter already referred to as obtained in the 135-foot focus camera.

The greatest extension obtained exceeds three diameters from the moon's limb. Here the streamers fade away into the background of sky, as if overpowered by skylight rather than as here ending.

5. *The combination of four wide-field cameras.*—These cameras were all in a measure successful, though not in equal measure, for one of the long-focus and one of the short-focus negatives was better than its mate, the former being on a better plate and in better focus, while the short-focus camera with screen showed unaccountable effects of motion not found in any others.

Comparing the long-focus with the short-focus negatives, the former were far superior both as corona pictures and as showing faint stars. One of the 11-foot focus negatives has probably the best general view of the corona secured by the expedition. (See Plate XVII.) On this plate the corona is seen as a whole. It hardly shows the full extent of the corona, which, as seen by the naked eye, extended to nearly three solar diameters, but it exhibits most clearly the curves on either side of the solar streamers, although perhaps not showing quite as great extension as that obtained with the 6-inch photographic telescope.

As regards faint stars and new objects, the better of the two 11-foot focus negatives covering the region west of the sun shows 114 stars, the faintest being of the 8.4 magnitude as given in Argelander's Durchmusterung, a result which, considering the amount of diffused light during the eclipse and the milkiness of the sky, is almost surprising. Six uncharted objects were found upon this plate, which appeared starlike and may conceivably be intra-mercurial planets, though nothing is to be understood as here predicated of them until a later and careful examination of the plates.

This photograph was unsuited for purposes of direct reproduction for the reason that the fainter stars required the best of conditions for seeing even on the original and would inevitably have been lost. It was nevertheless thought interesting to give an accurate map showing all the stars and suspects found, and this is done in Plate XVIII. The general reader will perhaps gain a better idea of the value of photography as an aid to investigation when he sees in this map, obtained in eighty-two seconds exposure, in a brighter than moonlit sky, not only the corona and the planet Mercury just beyond its rays, but more stars near the Pleiades than he can see with the unaided eye in the darkest night. Astronomers are invited to compare this map with the Durchmusterung charts, to see both the strong and the weak points of the plate. It will be recognized that the outer portions of the map show fainter stars than the middle part, and thus it is indicated that advantage in focus would have come if the plate had been slightly concave.

The negative covering the region east of the sun was much less satisfactory, and showed but 13 stars, the faintest being of the 6.3 magnitude. Two uncharted objects were found, but of their starlike character there is less certainty than in the case of four of the six discovered on the western plate.

The positions of these objects as interpolated on the Durchmusterung charts for the epoch 1855 and their approximate position for 1900 are as follows:

EPOCH 1855.

Right ascension.			Declination.		Magnitude.	Probability.
h.	*m.*	*s.*	°	′		
3	40	22	20	08	7.2	?
3	47	55	20	21	5 to 5.5	Good.
3	52	28	17	50	6.5	Do.
3	58	48	18	31	6.1	Do.
4	8	08	19	39	6.2	Do.
4	15	30	21	49	7.0	?
4	31	00	19	50	4.5	??
4	52	00	20	36	5.5 to 6.0	?

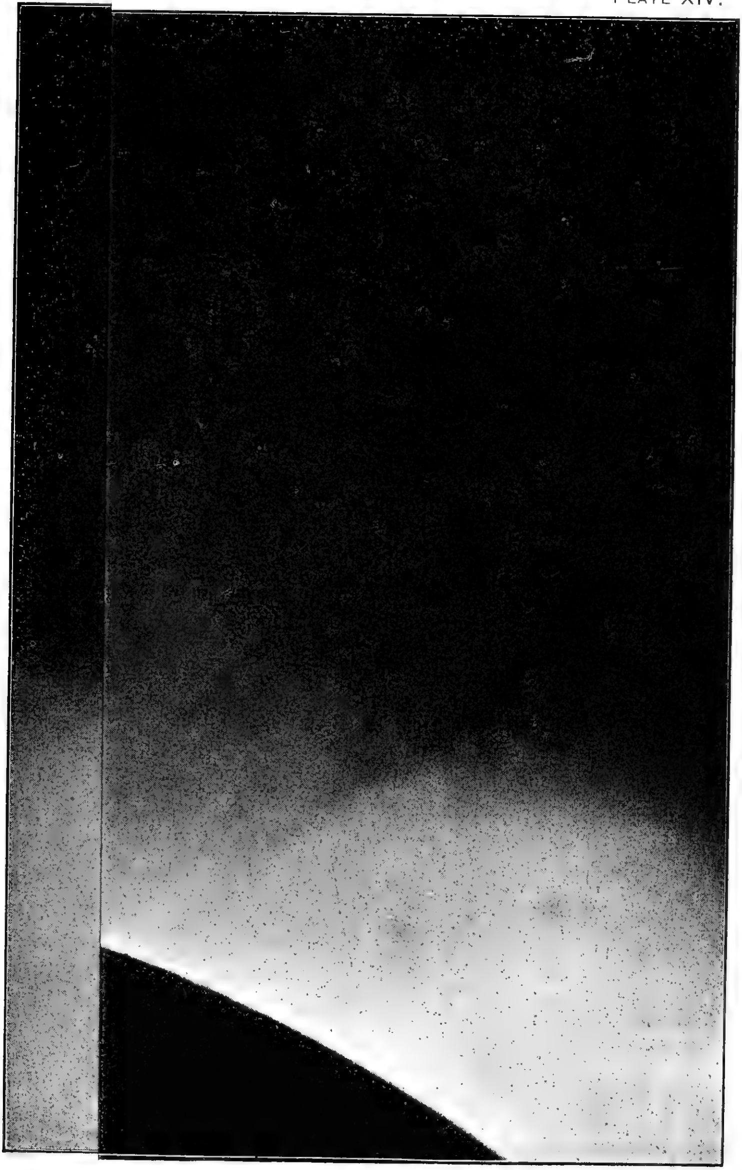
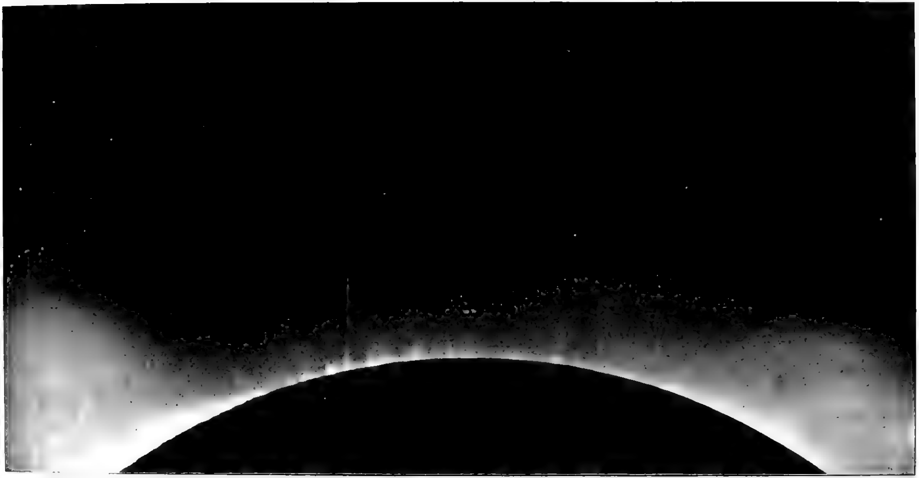
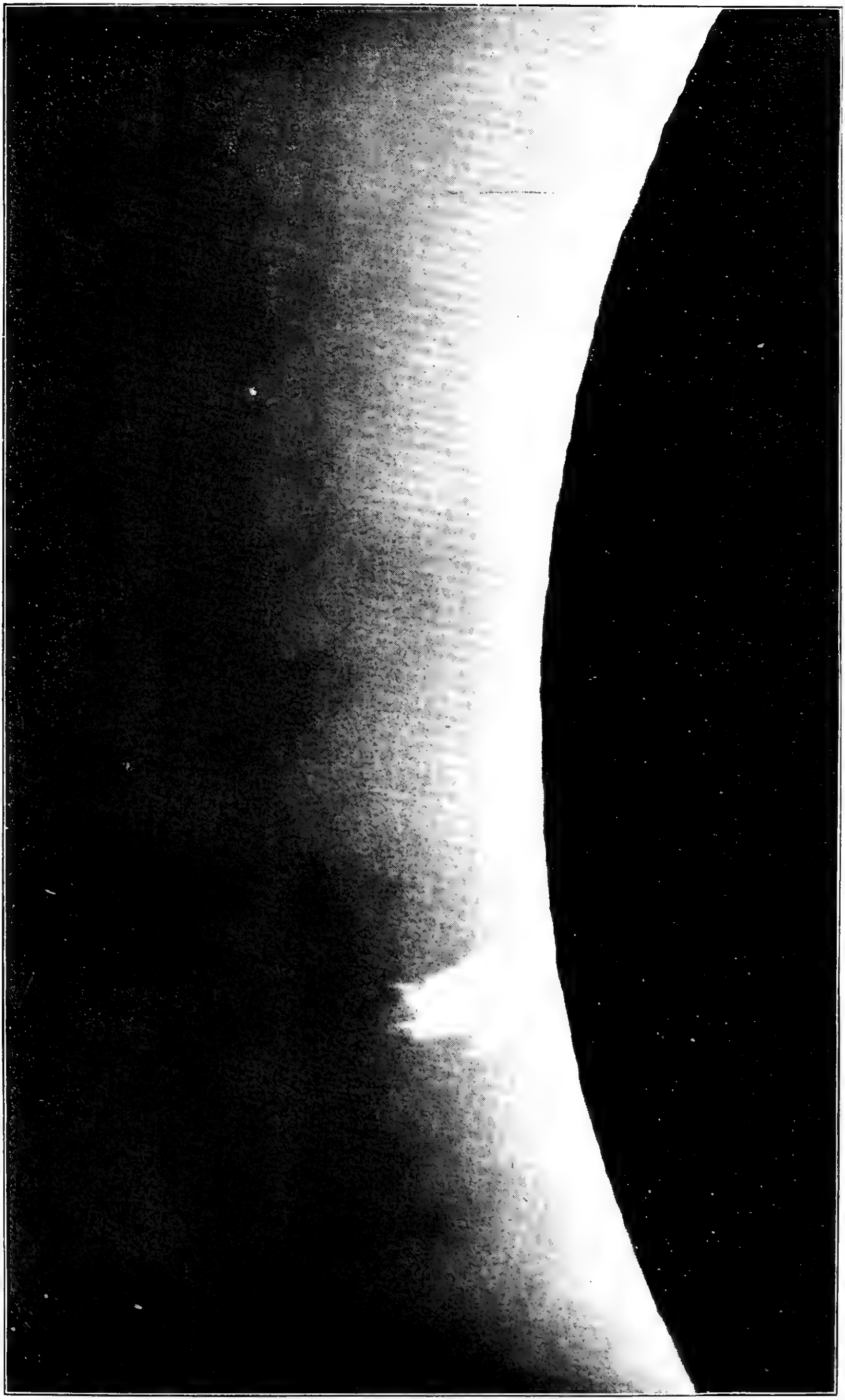


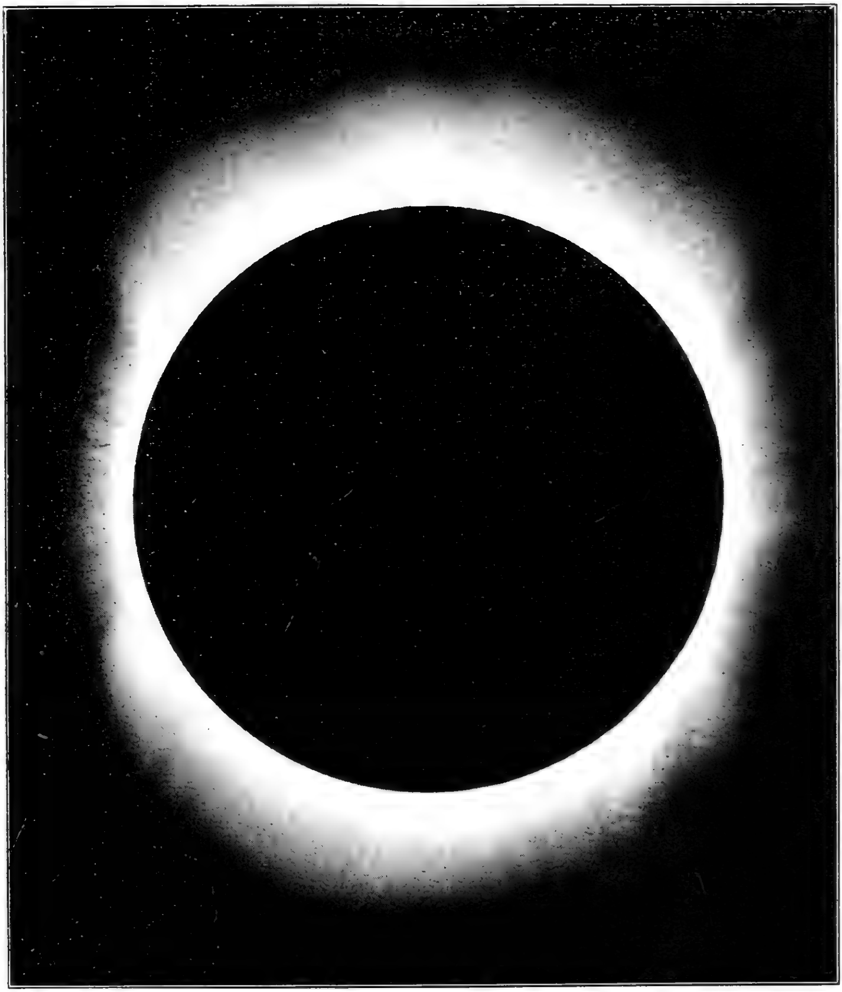
Plate XIV



Polar Streamers shown by the 12 inch Lens



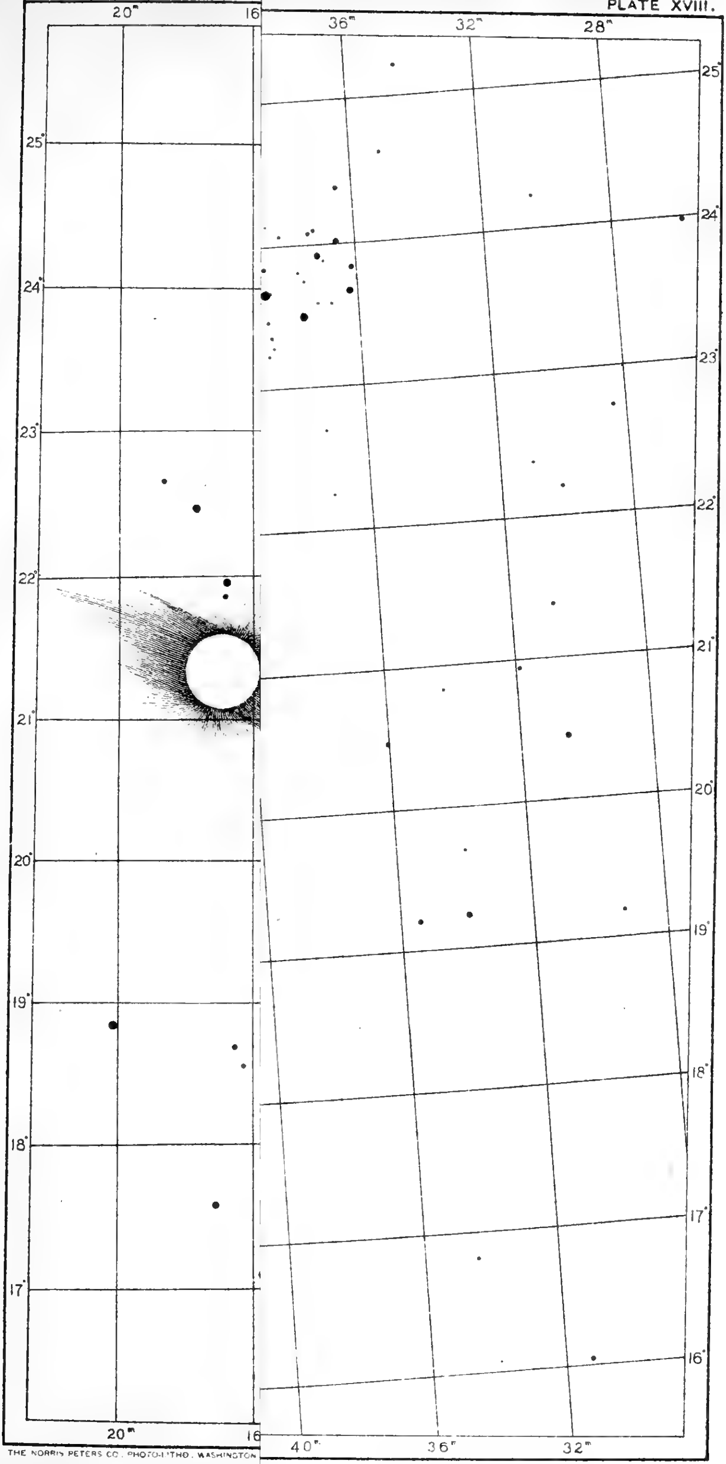
PROMINENCES SHOWN BY THE 12 INCH LENS.



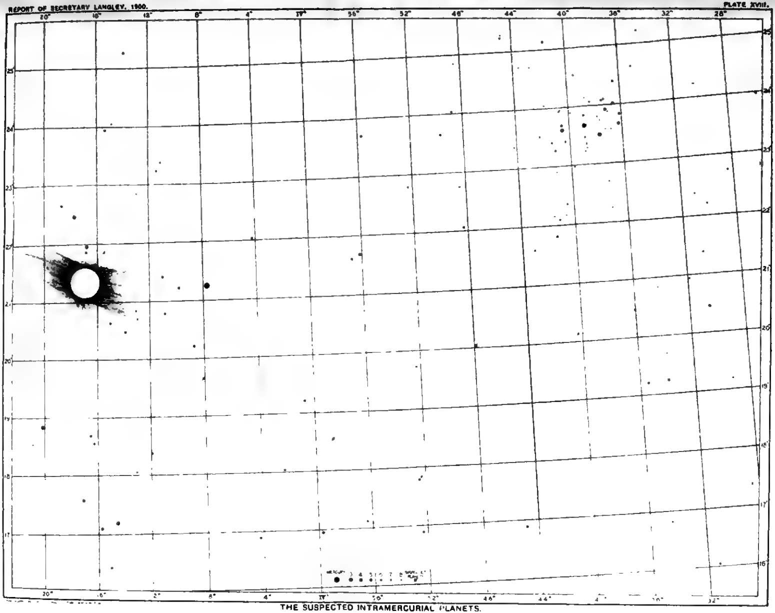
CORONA WITH 5-INCH LENS, SIX SECONDS' EXPOSURE.

GENERAL VIEW OF THE CORONA.

PLATE XVIII.



THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON



THE SUSPECTED INTRAMERCURIAL PLANETS.

EPOCH 1900.

Right ascension.	Declination.	Magnitude.	Probability.
h. m.	°		
3 42	20.2	7.2	?
3 50	20.3	5 to 5.5	Good.
3 55	17.9	6.5	Do.
4 1	17.6	6.1	Do.
4 11	19.8	6.2	Do.
4 18	21.9	7.0	?
4 34	19.9	4.5	??
4 55	20.7	5.5 to 6.0	?

Unfortunately we can not either confirm or reject these possible planets by obtaining additional evidence from the shorter-focus plates, excepting possibly in one instance, for near-by stars of about equal brightness are not shown on these other plates, so that the absence of the suspects is only natural. However, the negative taken with the 6-inch photographic telescope has a doubtful object precisely in the place of the suspect at right ascension (1855) 4 hours, 8 minutes, 8 seconds, but this is so faint as to be by no means a certain confirmation. It may be said with certainty that no new objects as bright as fourth magnitude were in the field.

It had been expected that other observers having similar apparatus would obtain additional evidence, but this, so far as learned, was not the case, and future eclipses must be awaited to settle the question of the possible intra-Mercurial planets.

6. *With the bolometric apparatus.*—The heat of the inner corona was successfully observed, and caused a deflection of 5 divisions as compared with the dark surface of the moon, but its spectrum was too faint to observe with the bolometric apparatus. Both the moon and the corona gave *negative* deflections (18 and 13 divisions respectively) as compared with screens at the temperature of the bolometer, while with only one five-hundredth the aperture the sky where the inner corona was about to appear gave *positive* deflections as compared with the screens, decreasing from 80 to 5 divisions during the five minutes preceding the totality.

These observations indicate not only that the coronal radiation is very slight, but that the *apparent* temperature of the inner corona is below 20° C. For it will be noticed that the bolometer *lost heat by radiation to the corona*, as evidenced by a negative deflection. Hence, when we consider its visual photometric brightness at the point where the bolometric measures were taken, which, judging from the results obtained by several observers during the eclipses of 1870, 1878, and 1898, was at least equal to that of the full moon, it is difficult to understand how the light of the corona can be due largely to reflection of rays from the sun or even to the incandescence of dust particles, for from sources of these kinds, which emit a great preponderance of invisible infra-red rays, the bolometer would have given large positive deflections.

Thus during observations taken two days before the full moon of August, 1900, with apparatus as nearly as possible identical with that used at Wadesboro, but unfortunately with a very hazy and humid and even cloudy atmosphere, *positive* deflections of 55 divisions were obtained from the moon as compared with a screen at the temperature of the bolometer, and 86 divisions as compared with the dark zenith sky.[1]

Observations on the daylight sky at a distance from the sun also resulted in large positive deflections.

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[1] As appears in the Allegheny researches on the temperature of the moon, these deflections would undoubtedly have been considerably increased had they been made in a clear and dry atmosphere at the time of the full moon.

In the case of the moon, as you have shown, about three-fourths of the deflection is due to the radiations of the moon itself, whose surface is slightly warmed by the solar rays, the remaining one-fourth being due to direct reflection of solar rays; but in the case of the daylight sky it was found here that the quality of the radiations was almost the same as that of the rays direct from the sun, so that the heating of the bolometer in this case is almost solely by direct reflection and not from primary radiations due to first warming of dust or other particles in the air.

The important result of a comparison of the radiations of the inner corona, the full moon, and the daylight sky somewhat remote from the sun is that while the three are roughly of equal visual brightness, the corona is effectively a cool and far from intense source, while the moon and the sky are effectively warm and many fold richer in radiation. Hence it would appear plausible to suppose that the corona merely sends out visible rays and that its light is not associated with the great preponderance of long wave-length rays proper to the radiation from bodies at a high temperature. If this be so, the coronal radiation might be compared with that from the positive electrical discharge in vacuum tubes, in which, as researches of K. Ängstrom and R. W. Wood have shown, there is neither an infra-red spectrum nor a high temperature. I am not sure whether this analogy can safely be carried further to explain the coronal constitution, but it may be recalled that the earth has in the aurora an electrical phenomenon of this nature; that the coronal streamers appear not unlike an electrical discharge; that the observed polarization of the coronal light is perhaps not necessarily by reflection, for polarization may be otherwise caused, as by the emission or absorption of bodies of peculiar internal structure, or even by magnetic influences, as in the Zeeman effect; that the corona does not seem to grow more red as it recedes from the sun, as we should expect incandescent dust to do, and finally the evidence of coronal spectroscopy seems not inconsistent with the hypothesis of a glow electrical discharge.

7. *With visual telescopes.*—I understand that in your own view, with the 5-inch equatorial, the inner corona appeared to have a much less minutely divided structure than that of 1878, and to be chiefly noticeable in its equatorial as opposed to its polar extensions. Prominences were plainly seen, and especially one large one at the southwest limb.

Mr. Child, with the 6-inch, being the artist of the party, made sketches from which he later prepared in pastel color a representation of the corona and prominences strikingly in accord with the photographs which were subsequently developed.

Rev. Father Woodman, with the 3½-inch, received impressions similar to those of the other visual observers.

8. *Times of contact.*—Mr. Putnam, a part of whose duty it was to direct the giving of signals, observed first, second, and fourth contacts, but missed the third in consequence of being hindered by directing the last signal.

His observations, reduced to seventy-fifth meridian mean time, are as follows:

	h.	*m.*	*s.*
First contact	19	36	19.7
Second contact	20	45	15.5
Fourth contact	22	05	37.3

Father Woodman's observations are as follows:

	h.	*m.*	*s.*
First contact	19	36	21
Second contact	20	45	16
Third contact	20	46	47
Fourth contact	22	05	26

The photographic contact camera furnished apparently excellent records of first, third, and fourth contacts. These have not been finally reduced, but it is found more difficult to determine the times from them than was expected, and it seems doubtful if this method is desirable to be employed in future.

9. Position of the camp.—From observations of stars made on five nights, taken in connection with noon-time signals transmitted from the United States Naval Observatory, Mr. Putnam determined the latitude and longitude of the camp to be:

Latitude	34°	57′	52″	north.
Longitude	80°	04′	27″	(west of Greenwich.)
	5h.	20m.	17.8s.	

SUMMARY.

The operations of the Astrophysical Observatory during the past year have been distinguished, first, by the publication of the first volume of its Annals, in which the infra-red solar spectrum is the main topic; second, by progress in the preparation of a highly sensitive, steady, and magnetically shielded galvanometer; third, by observations of the total solar eclipse, in which excellent large-scale photographs by the corona were secured, the coronal extensions photographed to upward of three diameters from the moon's limb, the absence of intra-mercurial planets above the fourth magnitude made nearly certain and the presence of several such between the fifth and seventh magnitude rendered as probable as single photographs can do, and finally, in which the small but measurable intensity of the total radiations and the effectively low temperature of the inner corona were observed by the aid of the bolometer.

Respectfully submitted.

C. G. Abbot,
Aid Acting in Charge Astrophysical Observatory.

Mr. S. P. Langley,
Secretary of the Smithsonian Institution, Washington, D. C.

APPENDIX VI.

REPORT OF THE LIBRARIAN FOR THE YEAR ENDED JUNE 30, 1900.

SIR: I have the honor to present herewith the report of the operations of the library of the Smithsonian Institution for the fiscal year ended June 30, 1900.

	Quarto or larger.	Octavo or smaller.	Total.
Volumes	669	1,383	2,052
Parts of volumes	10,294	4,163	14,457
Pamphlets	813	5,538	6,351
Charts			841
Total			23,701

The accession numbers in the record book run from 413773 to 431970.

The additions to the Secretary's library, the office library, and the library of the Astrophysical Observatory number 386 volumes and pamphlets and 1,484 parts of volumes, making a total of 1,870 and a grand total of 25,571. The gain in volumes and pamphlets and loss in parts of volumes, as shown in the above statement, is accounted for by the system of recording accessions begun January 1, 1900.

It has been the practice hitherto to record in the accession book each separate item, and while this plan rendered it possible to have a permanent record of every publication, the labor involved became very great. The necessity for it had disappeared to a certain extent since the use of card records, and after careful consideration it seemed best to institute the system of recording only completed volumes of periodicals and transactions (which form the bulk of the Institution's library) in the accession book.

In accordance with the general plan for the increase of the library, 808 letters were written for new exchanges and for completing series already in the library. As a result 213 new periodicals were added to the list, and 309 defective series were either completed or added to, as far as the publishers could supply the missing parts.

The library of the National Museum has been increased during the year by 15,606 books, pamphlets, and parts of periodicals, 6,988 of which were from the Smithsonian Institution, and the remainder directly to the Museum, secured either by gift, purchase, or exchange. The Museum library now consists of a central reference library and of 27 sectional libraries, and the collection is constantly growing in size and value. A more detailed account of its operations is presented in connection with the report of the Museum.

Besides the periodical room and the reference room, the library of the Institution now includes several small but carefully selected collections: The Secretary's library, the art collection, the sectional library of Aerodromics, and the law reference section. The small collection of the Astrophysical Observatory and of the National Zoological Park are also under the Librarian's care. All the library interests of the Institution and its bureaus, with the single exception of the Bureau of Ethnology, are centered in one office.

The number of books and bound periodicals in the circulating library established for the employees is 1,220; 1,824 volumes circulated among 115 readers, and the current periodicals were largely used. The pleasure and instruction afforded the employees of the Institution and Museum by this small collection amply justifies the extremely moderate outlay.

The inaugural dissertations and academic publications of the following universities have been accessioned: Basel, Berlin, Bern, Bonn, Breslau, Cornell, Erlangen, Freidburg, Geissen, Gratz, Griefswald, Halle a. S. Heidelberg, Helsingfors, Jena, Johns Hopkins, Jurjew, Kiel, Königsberg, Leipzig, Louvain, Lund, Marburg, Rostock, St. Petersburg, Strassburg, Toulouse, Tubingen, Utrecht, Würzburg, and Zurich.

Very respectfully,

Cyrus Adler, *Librarian.*

Mr. S. P. Langley,
Secretary Smithsonian Institution.

APPENDIX VII.

REPORT OF THE EDITOR.

SIR: I have the honor to submit the following report on the publications of the Smithsonian Institution for the year ending June 30, 1900:

I. SMITHSONIAN CONTRIBUTIONS TO KNOWLEDGE.

No memoir of the series of contributions was published during the year.

II. SMITHSONIAN MISCELLANEOUS COLLECTIONS.

Of the series of miscellaneous collections there has been nearly completed during the year a bibliography of Academic Chemical Dissertations to form a Second Supplement to the Select Bibliography of Chemistry by H. C. Bolton, published several years ago, and to which a First Supplement was published in January 1899.

The first volume of the Miscellaneous Collections, published in 1862, comprised 738 pages of directions for meteorological observations, and psychrometrical, meteorological, and physical tables. In the second volume were catalogues of birds, reptiles, shells, and other natural history and anthropological subjects. The third and fourth and sixth volumes were devoted almost entirely to catalogues and classifications of insects. In the fifth volume was a bibliography of conchology and lists of Smithsonian publications and correspondents. The seventh volume was a monograph on bats, with check lists of fossils, descriptions of land and fresh-water shells, etc. The eighth volume included catalogues and descriptions of insects, shells, arrangement of families of birds, circulars to collectors, etc. The ninth volume was composed of a bibliography of conchology and a catalogue of society publications. In the tenth volume were printed exhaustive works on mollusks, etc., and in the eleventh was given a classification of families of mammals and fishes, classification of insects, etc. A review of American birds in the Museum of the Smithsonian Institution by Professor Baird, and Clarke's Specific Gravity Tables comprised the twelfth volume.

Without reviewing each of the subsequent volumes, it may suffice to say that after publication funds became available for the use of the National Museum, very many papers of the Miscellaneous Collection class were printed in the Museum Proceedings and Bulletins, and for a time these were reprinted in the miscellaneous series.

III. SMITHSONIAN ANNUAL REPORTS.

The Annual Report for 1897 is in three volumes—one devoted to the Institution proper, one to the National Museum, and a third volume comprising some of the most important papers published by the late assistant secretary, G. Brown Goode. The latter volume is not completed, but the first two volumes have been distributed. Both the Smithsonian and Museum volumes of the 1898 Report were practically completed during the year, but it was not possible to make a general distribution of them. Progress was made in the preparation of the Report for 1899, though no portion was put in type except the Secretary's Report to the Board of Regents.

Annual Report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution for the year ending

June 30, 1897. Report of the U. S. National Museum, Part I, Washington: Government Printing Office, 1899. 8°. XXVII + 1021 pages, with 150 plates.

Annual Report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution for the year ending June 30, 1898. Washington: Government Printing Office. 1899. 8°. LV + 713 pages, with 13 plates and 3 maps.

Annual Report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the institution for the year ending June 30, 1898. Report of the U. S. National Museum. Washington: Government Printing Office. 1900. XVIII + 1294 pages, with 36 plates.

IV. SEPARATES FROM THE SMITHSONIAN REPORTS.

1172. The Latimer Collection of Antiquities from Porto Rico in the National Museum and The Guesde Collection of Antiquities in Pointe-a-Pitre, Guadeloupe, West Indies. By Otis T. Mason. (From the Smithsonian Reports of 1876 and 1884.) Washington. 1899. 8°. pp. IV, 372–939, 731–837.

1178. Report of S. P. Langley, Secretary of the Smithsonian Institution, for the year ending June 30, 1899. Washington: Government Printing Office. 1899. 8°. III + 81 pages, with 5 plates and a colored map.

1181. Journal of Proceedings of the Board of Regents of the Smithsonian Institution, Report of Executive Committee, Acts and Resolutions of Congress. (From the Smithsonian Report for 1898, pp. XI–LV.) Octavo pamphlet.

1182. Recent Progress accomplished by Aid of Photography in the Study of the Lunar Surface, by MM. Loewy and Puiseux. (From the Smithsonian Report for 1898, pages 105–121, with 3 plates.) Octavo pamphlet.

1183. The Function of Large Telescopes, by George E. Hale. (From the Smithsonian Report for 1898, pages 123–137.) Octavo pamphlet.

1184. The Le Sage Theory of Gravitation, by M. Le Sage, with introduction by S. P. Langley. (From the Smithsonian Report for 1898, pages 139–160.) Octavo pamphlet.

1185. The Extreme Infra-Red Radiations, by C. E. Guillaume. (From the Smithsonian Report for 1898, pages 161–165.) Octavo pamphlet.

1186. The Chemistry of the Stars, by Sir Norman Lockyer. (From the Smithsonian Report for 1898, pages 167–178.) Octavo pamphlet.

1187. The Perception of Light and Color, by Georges Lechalas. (From the Smithsonian Report for 1898, pages 179–196.) Octavo pamphlet.

1188. Some Curiosities of Vision, by Shelford Bidwell. (From the Smithsonian Report for 1898, pages 197–207.) Octavo pamphlet.

1189. Progress in Color Photography, by G. H. Niewenglowski. (From the Smithsonian Report for 1898, pages 209–215.) Octavo pamphlet.

1190. The Development of Electrical Science, by Thomas Gray. (From the Smithsonian Report for 1898, pages 217–234.) Octavo pamphlet.

1191. Telegraphy Across Space, by Silvanus P. Thompson. (From the Smithsonian Report for 1898, pages 235–247.) Octavo pamphlet.

1192. Signaling Through Space without Wires, by W. H. Preece. (From the Smithsonian Report for 1898, pages 249–257.) Octavo pamphlet.

1193. Note on the Liquefaction of Hydrogen and Helium, by Professor James Dewar. (From the Smithsonian Report for 1898, pages 259–266.) Octavo pamphlet.

1194. The Recently Discovered Gases and their Relation to the Periodic Law, by William Ramsay. (From the Smithsonian Report for 1898, pages 267–276.) Octavo pamphlet.

1195. The Kinetic Theory of Gases and Some of its Consequences, by William Ramsay. (From the Smithsonian Report for 1898, pages 277–287.) Octavo pamphlet.

1196. The Revival of Inorganic Chemistry, by H. N. Stokes. (From the Smithsonian Report for 1898, pages 289–306.) Octavo pamphlet.

1197. Scientific Ballooning, by Reverend John M. Bacon. (From the Smithsonian Report for 1898, pages 307–319.) Octavo pamphlet.

1198. The Tundras and Steppes of Prehistoric Europe, by Professor James Geikie. (From the Smithsonian Report for 1898, pages 321–347, with colored map.) Octavo pamphlet.

1199. Modification of the Great Lakes by Earth Movement, by C. K. Gilbert. (From the Smithsonian Report for 1898, pages 349–361.) Octavo pamphlet.

1200. The Plan of the Earth and its Causes, by J. W. Gregory. (From the Smithsonian Report for 1898, pages 363–388.) Octavo pamphlet.

1201. Funafuti: The Story of a Coral Atoll, by W. J. Sollas. (From the Smithsonian Report for 1898, pages 389–406.) Octavo pamphlet.

1202. Oceanography, by M. J. Thoulet. (From the Smithsonian Report for 1898, pages 407–425.) Octavo pamphlet.

1203. The Relation of Plant Physiology to the Other Sciences, by Doctor Julius Wiesner. (From the Smithsonian Report for 1898, pages 427–444. (Octavo pamphlet.

1204. Pithecanthropus erectus: A form from the Ancestral Stock of Mankind, by Eugene Dubois. (From the Smithsonian Report for 1898, pages 445–459, with three plates.) Octavo pamphlet.

1205. On our Present Knowledge of the Origin of Man, by Ernst Haeckel. (From the Smithsonian Report for 1898, pages 461–480.) Octavo pamphlet.

1206. The Laws of Orientation among Animals, by Captain G. Reynaud. (From the Smithsonian Report for 1898, pages 481–498.) Octavo pamphlet.

1207. The Fresh-Water Biological Stations of the World, by Henry B. Ward. (From the Smithsonian Report for 1898, pages 499–513.) Octavo pamphlet.

1208. The Theory of Energy and the Living World. The Physiology of Alimentation. By A. Dastre. (From the Smithsonian Report for 1898, pages 515–549.) Octavo pamphlet.

1209. The Economic Status of Insects as a Class, by L. O. Howard. (From the Smithsonian Report for 1898, pages 551–569.) Octavo pamphlet.

1210. Recent Advances in Science, and their Bearing on Medicine and Surgery, by Professor R. Virchow. (From the Smithsonian Report for 1898, pages 571–578.) Octavo pamphlet.

1211. A Sketch of Babylonian Society, by F. E. Peiser. (From the Smithsonian Report for 1898, pages 579–599.) Octavo pamphlet.

1212. The Excavations of Carthage, by Philippe Berger. (From the Smithsonian Report for 1898, pages 601–614.) Octavo pamphlet.

1213. The Transportation and Lifting of Heavy Bodies by the Ancients, by J. Elfreth Watkins. (From the Smithsonian Report for 1898, pages 615–619, with 4 plates.) Octavo pamphlet.

1214. The Past Progress and Present Position of the Anthropological Sciences, by E. W. Brabrook. (From the Smithsonian Report for 1898, pages 621–636.) Octavo pamphlet.

1215. The Origin of African Civilizations, by L. Frobenius. (From the Smithsonian Report for 1898, pages 637–650, with a colored map.) Octavo pamphlet.

1216. Dogs and Savages, by Doctor B. Langkavel. (From the Smithsonian Report for 1898, pages 651–675.) Octavo pamphlet.

1217. The Life and Works of Brown-Séquard, by M. Berthelot. (From the Smithsonian Report for 1898, pages 677–969.) Octavo pamphlet.

Report upon the condition and progress of the U. S. National Museum during the year ending June 30, 1897, by Charles D. Walcott, acting assistant secretary of the Smithsonian Institution in charge of the U. S. National Museum. (From the Annual Report of the U. S. National Museum for 1897, pages 1–245.) Octavo pamphlet.

Recent Foraminifera. A Descriptive Catalogue of Specimens dredged by the U. S. Fish Commission Steamer Albatross. By James M. Flint, M.D., U. S. N., honorary curator, Division of Medicine, U. S. National Museum. (From the Annual Report of the U. S. National Museum for 1897, pages 249–349, with 80 plates.) Octavo pamphlet.

Pipes and Smoking Customs of the American Aborigines, based on material in the U. S. National Museum, by Joseph D. McGuire. (From the Annual Report of the U. S. National Museum for 1897, pages 351–645, with 5 plates.) Octavo pamphlet.

Catalogue of the Series Illustrating the Properties of Minerals, by Wirt Tassin, assistant curator, Division of Mineralogy. (From the Annual Report of the U. S. National Museum for 1897, pages 647–688.) Octavo pamphlet.

Te Pito Te Henua, known as Rapa Nui; commonly called Easter Island, South Pacific Ocean, by George H. Cooke, surgeon, U. S. Navy. (From the Annual Report of the U. S. National Museum for 1897, pages 689–723.) Octavo pamphlet.

The Man's Knife among the North American Indians, a Study in the Collections of the U. S. National Museum, by Otis Tufton Mason, curator, Division of Ethnology. (From the Annual Report of the U. S. National Museum for 1897, pages 725–745.) Octavo pamphlet.

Classification of the Mineral Collections in the U. S. National Museum, by Wirt Tassin, assistant curator, Division of Mineralogy. (From the Annual Report of the U. S. National Museum for 1897, pages 747–810.) Octavo pamphlet.

Arrowpoints, Spearheads, and Knives of Prehistoric Times, by Thomas Wilson, curator, Division of Prehistoric Archæology. (From the Annual Report of the U. S. National Museum for 1897, pages 811–988, with 65 plates.) Octavo pamphlet.

V. PUBLICATIONS OF THE NATIONAL MUSEUM.

Proceedings of the United States National Museum, Volume XXI. Published under the direction of the Smithsonian Institution. Washington: Government Printing Office. 1899. 8°. XIII + 933 pages, with 89 plates.

The contents of this volume were enumerated in the editor's report for last year.

During the present fiscal year the following articles from Volume XXII of Proceedings have been printed and distributed:

Proc. 1179. The Osteological Characters of the Fishes of the Suborder Percesoces, by Edwin Chapin Starks. 8°. pp. 1–10, with plates I–III.

Proc. 1180. Notes on Birds from the Cameroons District, West Africa, by Harry C. Oberholser. 8°. pp. 11–19.

Proc. 1181. Descriptions of two new Species of Tortoises from the Tertiary of the United States, by O. P. Hay. 8°. pp. 21–24, with plates IV–VI.

Proc. 1182. A List of the Birds collected by Mr. R. P. Currie in Liberia. 8°. pp. 25–37, with plate VII.

Proc. 1183. A List of the Biting Lice (Mallophaga) taken from Birds and Mammals of North America, by Vernon L. Kellogg. 8°. pp. 39–100.

Proc. 1184. New Species of Nocturnal Moths of the Genus Campometra, and Notes, by John B. Smith. 8°. pp. 101–105.

Proc. 1185. Synopsis of the Solenidæ of North America and the Antilles, by William H. Dall. 8°. pp. 107–112.

Proc. 1186. The Osteology and Relationship of the Percoidean Fish, Dinolestes lewini, by Edwin Chapin Starks. 8°. pp. 113–120, with plates VIII–XI.

Proc. 1187. Description of two New Species of Crayfish, by W. P. Hay. 8°. pp. 121–123.

Proc. 1188. Contributions to the Natural History of the Commander Islands. No. XIII. A New Species of Stalked Medusae, Haliclystus stejnegeri, by K. Kishinouye. 8°. pp. 125–129.

Proc. 1189. Description of a New Species of Idotea from Hakodate Bay, Japan, by Harriet Richardson. 8°. pp. 131–134.

Proc. 1190. List of Shells collected by Vernon Bailey in Heron and Eagle lakes, Minnesota, with Notes, by Robert E. C. Stearns. 8°. pp. 135–138.

Proc. 1191. Description of a New Variety of Haliotis from California, with faunal and geographical notes, by Robert E. C. Stearns. 8°. pp. 139–142.

Proc. 1192. On the Lower Silurian (Trenton) Fauna of Baffin Land, by Charles Schuchert. 8°. pp. 143–177, with plates XII–XIV.

Proc. 1193. Some Neocene Corals of the United States, by Henry Stewart Gane. 8°. pp. 179–198, with plate XV.

Proc. 1194. A New Fossil Species of Caryophyllia from California, and a New Genus and Species of Turbinolid Coral from Japan, by T. Wayland Vaughan. 8°. pp. 199–203, with plate XVI.

Proc. 1195. Notes on Birds Collected by Dr. W. L. Abbott in Central Asia, by Harry C. Oberholser. 8°. pp. 205–228.

Proc. 1196. Notes on Some Birds from Santa Barbara Islands, California, by Harry C. Oberholser. 8°. pp. 229–234.

Proc. 1197. Catalogue of a Collection of Birds from Madagascar, by Harry C. Oberholser. 8°. pp. 235–248.

Proc. 1198. Report on a Collection of Dipterous Insects from Puerto Rico, by D. W. Coquillett. 8°. pp. 249–270.

Proc. 1199. The Decapod Crustaceans of West Africa, by Mary J. Rathbun. 8°. pp. 271–316.

Proc. 1200. Description of a New Bird of the Genus Dendrornis, by Charles W. Richmond. 8°. pp. 317, 318.

Proc. 1201. Descriptions of New Birds from Lower Siam, by Charles W. Richmond. 8°. pp. 319–321.

Proc. 1202. On the Genera of the Chalcid-flies belonging to the Subfamily Encyrtinae, by William H. Ashmead. 3°. pp. 323–412.

Part 4 of Bulletin 47, entitled "The Fishes of North and Middle America," by Doctors Jordan and Evermann, was issued before the close of the fiscal year. This volume, which contains 392 plates, with explanations and a general table of contents, completes one of the most important works thus far published in the Bulletin series.

Bulletin of the United States National Museum, No. 47. The Fishes of North and Middle America. By David Starr Jordan and Barton Warren Evermann. Part IV. Washington: Government Printing Office. 1900. 8°. pp. CI, 3137–3313, Plates I–CCCXCII.

The Methods Employed at the Naples Zoological Station for the Preservation of Marine Animals, by Salvatore Lo Bianco. Translated from the original Italian by Edmund Otis Hovey. Bull. U. S. Nat. Mus., No. 39, Part M, Oct. 2, 1899, pp. [1]–[42].

Directions for Preparing Study Specimens of Small Mammals, by Gerrit S. Miller, jr. Bull. U. S. Nat. Mus., No. 39, Part N, Aug. 26, 1899, pp. [1]–[10], with 1 fig.

Directions for Collecting and Rearing Dragon Flies, Stone Flies, and May Flies, by James G. Needham. Bull. U. S. Nat. Mus., No. 39, Part O, Nov. 29, 1899, pp. [1]–[9], with figs. 1–4.

VI. ANNALS OF ASTROPHYSICAL OBSERVATORY.

Annals of the Astrophysical Observatory of the Smithsonian Institution. Volume I. By S. P. Langley, Director, aided by C. G. Abbot. Washington: Government Printing Office. 1900. Quarto, pp. vii, 266, with 36 plates.

VII. PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY.

Part 2 of the Seventeenth Annual Report of the Bureau of American Ethnology was published during the year, but the completion of Part I has been delayed. The printing of the Eighteenth Report was nearly completed, and the Nineteenth Report was transmitted to the Public Printer. Some progress was also made in the printing of the first bulletin of the new series authorized by Congress.

Seventeenth Annual Report of the Bureau of American Ethnology to the Secretary of the Smithsonian Institution, 1895–96, by J. W. Powell, Director. Part 2. (Navaho Houses, by Cosmos Mindeleff.) Washington: Government Printing Office. 1898. Royal octavo, pp. 469–752, with plates lxxxii–xc, and figures 230–244.

VII. AMERICAN HISTORICAL ASSOCIATION.

The Annual Report of the American Historical Association for the year 1898 was completed during the year, and the report for 1899 was transmitted to the Public Printer. In the editor's report for last year the contents of the 1898 volume were enumerated. The 1899 report will be in two volumes, the second volume comprising the correspondence of John C. Calhoun. In the first volume are the following papers:

Report of Proceedings of Fifteenth Annual Meeting in Boston and Cambridge, December 27–29, 1899, by A. Howard Clark.

Inaugural Address on History, by James Ford Rhodes, President.

Removal of Officials by the Presidents of the United States, by Carl Russell Fish.

Legal Qualifications for Office in America, 1619–1899, by Frank Hayden Miller.

The Proposed Absorption of Mexico in 1847–48, by Edward G. Bourne.

The Problem of Chinese Immigration in Farther Asia, by Frederick Wells Williams.

The Droit de Banalité during the French Régime in Canada, by W. Bennett Munro.

The Restoration of the Proprietary in Maryland and the Legislation against the Roman Catholics during the Governorship of Capt. John Hart (1714–1720), by Barnard C. Steiner.

The First Criminal Code of Virginia, by Walter F. Prince.

A Critical Examination of Gordon's History of the American Revolution, by Orin Grant Libby.

A Recent Service of Church History to the Church, by William Given Andrews.

The Origin of the Local Interdict, by Arthur Charles Howland.

The Poor Priests: A Study in the Rise of English Lollardry, by Henry Lewin Cannon.

The Roman City of Langres (France) in the Early Middle Ages, by Earle Wilbur Dow.

Robert Fruin, 1823–1899: A Memorial Sketch, by Ruth Putnam.

Sacred and Profane History, by James Harvey Robinson.

Should Recent European History have a Place in the College Curriculum? by Charles M. Andrews.

The Colonial Problem, by Henry E. Bourne.

A Bibliography of the Study and Teaching of History, by James Ingersoll Wyer.

Titles of Books on English History published in 1897 and 1898, selected and annotated by W. Dawson Johnston.

A Bibliography of Mississippi, by Thomas McAdory Owen.

Bibliography of Publications of the American Historical Association, 1885 to 1900.

IX. REPORT OF THE DAUGHTERS OF THE AMERICAN REVOLUTION.

The Second Report of the National Society of the Daughters of the American Revolution was transmitted to Congress in accordance with the act of incorporation of that body, but as only the regular document edition was printed by Congress no copies were received by the Institution.

Respectfully submitted.

A. Howard Clark, *Editor.*

Mr. S. P. Langley,
Secretary Smithsonian Institution.

GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1900.

ADVERTISEMENT.

The object of the GENERAL APPENDIX to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discoveries in particular directions; reports of investigations made by collaborators of the Institution, and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution, from a very early date, to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and this purpose has, during the greater part of its history, been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880 the Secretary, induced in part by the discontinuance of an annual summary of progress which for thirty years previous had been issued by well-known private publishing firms, had prepared by competent collaborators a series of abstracts, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report, for 1900.

PROGRESS IN ASTRONOMY DURING THE NINETEENTH CENTURY.[1]

By Sir Norman Lockyer.

In looking back over a century's work in the oldest of the sciences one is struck not only by the enormous advance that has been made in those branches of the science dealing with the motions of the heavenly bodies which were cultivated at least eight thousand years ago by early dwellers in the valleys of the Nile, Tigris, and Euphrates, but with the fact that during the century that is passing away a perfectly new science of astronomy has arisen. By annexing physics and chemistry astronomers now study the motions of the particles of which all celestial bodies are composed; a new molecular astronomy has now been firmly established side by side with the old molar astronomy which formerly alone occupied the thoughts of star gazers.

Along this new line our knowledge has advanced by leaps and bounds, and the results already obtained in expanding and perfecting man's views of nature in all her beauty and immensity are second to none which have been garnered during the last hundred years.

THE POSITION AT THE BEGINNING OF THE CENTURY.

It may be well before attempting to obtain a glimpse of recent progress that we should try to grasp the state of the science at the time when the nineteenth century was about to dawn, and this, perhaps, can be best accomplished by seeing what men were working at this period at which the greatest activity was to be found in Germany; there was no permanent observatory in the southern hemisphere or in the United States.

First and foremost among the workers—he has, in fact, been described as "the greatest of modern astronomers"—was William Herschel, a German domiciled in England. In the year 1773 he hired a telescope and with this small instrument he obtained his first glimpses of the rich fields of exploration open in the skies. From that time onward he had one fixed purpose in his mind, which was to obtain as intimate knowledge as possible of the construction of the heavens.

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To do this, of course, great optical power was necessary, and such was his energy that, as large instruments were not to be obtained at any price, he set to work and made them himself.

Herschel presented the beginning of the nineteenth century not only with a definite idea of the constitution of the stellar system, based on a connected body of facts and deductions from facts, as gleaned through his telescopes, but observations without number in many fields. He discovered a new planet, Uranus, and several satellites of the planets; published catalogues of nebulæ; established the gravitational bond between many "double stars;" and carried on observations of the sun, then supposed to be a habitable globe. What Herschel did for observational astronomy and deductions therefrom Laplace did for the furtherance of our knowledge concerning the exact motions of the bodies comprising the solar system. Newton had long before announced that gravitation was universal, and Laplace brought together investigations undertaken to determine the validity of this law. These were given to the world in his wonderful book on "Celestial Mechanics," the first volumes of which appeared in 1799.

A survey of the work of these two great astronomers gives one an idea of what was going on in observational and mathematical astronomy at the beginning of the century.

The study was now destined to make rapid strides, as not only were new optical instruments, some designed for special purposes, introduced, new mathematical processes applied, fresh fields for research opened up, but the number of workers was considerably augmented by the increased means available; so much so, indeed, that the first astronomical periodical was founded by Von Zach in 1800 to facilitate intercommunications between the observers.

The first evening of the nineteenth century (January 1, 1801) augured well for progress. It had long been thought that all the members of the solar system had not as yet been discovered, and there was a very notable gap between the planets Mars and Jupiter, indicated by Bode's law. Observers were organized to make a thorough search for the missing planet, portions of the sky being divided between them for minute examination. It fell to the Italian observer, Piazzi, to discover a small body which was moving in an orbit between these two planets, on the date named. The century thus began with a sensation, and, because the new body, which was named "Ceres," was not of sufficient size to be accepted as the "missing planet," the idea was suggested that perhaps it was a fragment of a larger planet that had been blown to pieces in the past.

An opportunity here arose for mathematical astronomy to come to the help of the observer, for Ceres soon was lost in the solar rays, and in order to rediscover it after it had passed conjunction an approximate knowledge of its path and future position was necessary.

With the then existing methods of computation of orbits it was imperative to have numerous measured positions to use as data for the calculation. The scanty data available in the case of Ceres were not sufficient for the application of the method. The occasion discovered a man, one of the greatest mathematicians of the nineteenth century, Karl Frederick Gauss, who, although only 25 years of age, undertook the solution of the problem by employing a system which he had devised, known as "the method of least squares," which enabled him to obtain a most probable result from a given set of observations.

This, with a more general method of orbit computation, also elaborated by himself, was sufficient to enable him to calculate future positions of Ceres, and on the anniversary of the original discovery, Olbers, another great pioneer in orbit calculations, found the planet in very nearly the position assigned by Gauss. So great was the curiosity regarding the other portions of the planet, which was supposed to have been shattered, that numerous observers at once commenced to search after other fragments.

These were the actualities of 1801 and thereabouts, but the seed of much future work was sown. Kant and Laplace had already occupied themselves with theories as to the world formation, and spectrum analysis as applied to the heavenly bodies may be said to have been started by Wollaston's observations of dark lines in the solar spectrum in 1802. Fraunhofer was then a boy at school. In the same year the first photographic prints were produced by Wedgewood and Davy.

OBSERVATORIES.

It has been stated that at the beginning of the century there were no permanent observatories, either in the southern hemisphere or in the United States. The end of the century finds us with two hundred observatories all told, of which fourteen are south of the equator and forty-seven in the United States, among which latter are the best equipped and most active in the world.

The observatory of Parramatta was the first established (in 1821) in the southern hemisphere. This was followed by that of the Cape of Good Hope in 1829. Of the more modern southern observatories from which the best work has come we may mention Cordova, the seat of Gould's important investigations, established in 1868, and Arequipa, a dependency of Harvard, whence the spectra of the southern stars have been secured, erected still more recently (1881).

I believe, but I do not know, that the large number of American observatories have radiated from Cincinnati, where, in consequence of eloquent appeals, both by voice and pen, from Mitchell, then professor of astronomy, an observatory was commenced in 1845. There can be no doubt that at the present moment, with the numerous well-equipped and active observatories, and the careful and thorough teaching established side by side with them, which enables numberless students to use the various instruments, the United States in matters astronomical fills the position occupied by Germany at the beginning of the century.

In Europe special observatories have been established at Meudon, Kensington, and Potsdam, so that new astrophysical inquiries may be undertaken without interfering with the prosecution or extension of the important meridional work carried on at Paris, Greenwich, and Berlin. A large proportion of the observations made by the Lick and Yerkes observatories in the United States has been astrophysical.

One of the special inquiries committed to the charge of the Solar Physics Observatory at Kensington at its establishment by the British Government had relation to the possibility of running home meteorological changes on the earth, especially those followed by drought and famines in various parts of the Empire, to the varying changes in the sun indicated by the ebb and flow of spots on its surface. With this end in view observations of the sun were commenced in India and the Mauritius to supplement those taken at Greenwich. At the same time other daily observations of sun spots by a different method were commenced at Kensington.

This kind of work was at first considered ideally useless; we shall see later on what has become of it.

IMPROVEMENTS IN TELESCOPES.

The progress in astronomical science throughout the closing century has naturally to a great extent depended upon the advances made both in the optics of the telescope and the way in which they are mounted, either with circles to record exact times and positions, or made to move so as to keep a star or other celestial objects in the field of view while under observation. The perfection of definition and the magnitude of the lenses employed in the modern instrument have been responsible for many important discoveries.

Ever since the telescope was invented—Galileo's lens was smaller than those used in spectacles—men's minds have been concentrated on producing instruments of larger and larger size to fathom the cosmos to its innermost depths.

At the beginning of this century we were, as we have seen already, in possession of reflectors of large dimensions; Herschel's 4-foot mirror, the instrument he was using in 1801, which had a focal length of 40 feet, was capable of being employed with high magnifying powers; and it was the judicious use of these, on occasions when the finest of weather prevailed, that enabled him to enrich so extensively our knowledge of the stellar and planetary systems. For the ordinary work of astronomy, however, especially when circles are used, refractors are the more suitable instruments. This form suffers less from the vicissitudes of weather and temperature, and is therefore more suited where exact measurements are required.

Toward the end of the eighteenth century a Swiss artisan, Pierre Guinard, after many years of patient labor, succeeded in producing pure disks of flint glass as large as 6 inches in diameter. The modern refracting telescope thus became possible.

In 1804 there was started at Munich the famous optical and mechanical institute which soon made its presence felt in the astronomical world. Reforms in instrument making were soon taken in hand, and under the leadership of the great German astronomer, Bessel, great strides were made in instruments of precision. Fraunhofer, who had been silently working away at the theory of lenses and making various experiments in the manufacture of glass, was joined in 1805 by Guinard. In 1809 Troughton invented a new method of graduating circles, according to Airy the greatest improvement ever achieved in the art of instrument making.

In 1824 Fraunhofer successfully completed and perfected an object glass of 9.9 inches in diameter for the Dorpat Observatory. This objective might literally have been called a "giant," for nothing approaching it in size had been previously made.

England, which was at one time the exclusive seat of the manufacture of refracting telescopes, was now completely outstripped by both Germany and France, and for this we had to thank "the short-sighted policy of the Government, which had placed an exorbitant duty on the manufacture of flint glass." In 1833 the Dorpat refractor was eclipsed by one of 15 inches' aperture, made for the Pulkowa Observatory by Merz & Mähler, Fraunhofer's successors, who, about ten years later, supplied a similar instrument to Harvard College. At this time Lord Rosse emulated with success the efforts of Herschel, and rehabilitated the reflector by producing a metallic mirror of 6-foot aperture and 54-foot focal length, which he mounted at Parsonstown. The speculum weighed no less than 4 tons. To mount this immense mass efficiently and safely was a work of no light nature, but he successfully accomplished it, and eventually both mirror and the telescope, which weighed now altogether 14 tons, were so well counterpoised that they could be easily moved in a limited direction by means of a windlass, worked by two men. The perfection of the "seeing" qualities of this instrument and its enormous light-grasping powers were particularly striking, and observational astronomy was considerably enriched by the discoveries made with it.

Speculum metal was not destined to stay. Ten years later (1857) the genius of Léon Foucault introduced glass mirrors with a thin coating of silver deposited chemically, and these have now universally superseded the metallic ones.

The long supremacy of Germany in the matter of refractors was broken down ultimately by the famous English optician and engineer, Thomas Cooke, of York. His first considerable instrument, one of 7 inches aperture, was finished in 1851, and in 1865, a year before his lamented death, he completed the first of our present giant refractors, one of 25 inches aperture, for Mr. Newell, of Gateshead. In consequence of the success of Cooke's achievement other large refractors were soon undertaken.

Alvan Clark, the famous optician of Cambridgeport, Mass., at once commenced a 26-inch for the Washington Observatory. The next was one of 27 inches, made by Grubb for the Vienna Observatory. Object glasses now grew inch by inch in size, depending on the increased dimensions of disks that could be satisfactorily cast. Gautier of Paris completed a 29½-inch for the Nice Observatory, while Alvan Clark made an objective of 30 inches for Pulkowa. In 1877 the latter successfully completed the mounting of an objective of 36 inches for the Lick Observatory, but this immense lens was only achieved after a great number of failures. Even this large object glass was surpassed in size by the completion in 1892 of the 40-inch, which he made for the Yerkes Observatory, and by that made by Gautier for the Paris Exhibition of 1900.

So much, then, for the largest refractors. In recent years, since the introduction of the silver on glass mirrors, with their stability of figure and brilliant surface, which can be easily renewed, reflectors of large apertures are again being produced. The first of these was one of 36 inches aperture made by Calver for Dr. Common, who demonstrated its fine qualities and his own skill by the beautiful photographs of the nebula of Orion he was enabled to secure with it. Dr. Common himself has since turned his attention to the making and silvering of large mirrors of this kind, and the largest he has actually completed and mounted equatorially is one with a diameter of 5 feet. Another of 36 inches aperture is in use at the Solar Physics Observatory, at Kensington.

The progress of depositing silver on glass has led of late years to important developments in which plane mirrors are used. Foucault was the first to utilize such mirrors in his siderostat, in which such a mirror is made to move in front of a horizontal fixed telescope, which may be of any focal length, and no expensive dome or rising floor is required. The plane mirror of the siderostat in the Paris Exhibition telescope is 6 feet in diameter.

A variation of this instrument is the cœlostat, more recently advocated by Lippmann. The Coudé equatorial mounting also depends upon the use of plane mirrors; with such a telescope the observer is at rest at a fixed eyepiece or camera in a room which may be kept at any temperature.

Now that in astronomical work eye observations are indispensably supplemented by the employment of photography, an important modification of the refracting telescope has become necessary. This was first suggested by Rutherfurd.

The ordinary achromatic object glass consists, as a rule, of two lenses, one made of flint and the other of crown glass; but in this form the photographic rays are not brought to the same focus as the visual rays. This, however, can be achieved by employing three lenses instead of two, each of different kinds of glass. The most modern improvement in the telescope is due to Mr. Dennis Taylor, of Cooke & Sons, and to Dr. Schott and Professor Abbe, whose researches in the manufacture of old and new varieties of optical glass have rendered Mr. Taylor's results feasible. By the Taylor lens outstanding color is abolished, all the rays being brought absolutely to the same focus. Such lenses can therefore be used either for visual observations or for photography for spectroscopy.

SPECTROSCOPIC ASTRONOMY.

The branch of physics which at the present day has assumed such mighty and far-reaching proportions in astronomical work is that dealing with spectrum analysis, which, although suggested as early as the time of Kepler, did not receive any impetus as regards its application to celestial bodies until the beginning of the present century at the hands of Wollaston and Fraunhofer. Then, however, it still lacked the chemical touch supplied afterward by Kirchhoff and Bunsen. They showed us that the spectrum observed when the light from any heated body is passed through a prism is an index to the chemical composition of the light source. The constitution of a vapor when in a condition to absorb light can be determined by an extension of the same principle first demonstrated by Stokes, Angström, and Balfour Stewart when the century was about half completed.

The first celestial body toward which the spectroscope was turned was our central luminary, the sun.

Wollaston first discovered that its spectrum was crossed by a few dark lines. We learned next from Fraunhofer, who in 1814 worked with instruments of greater power, that the solar spectrum was crossed not only by a few dark lines, but by some hundreds. Not content with examining the light of the sun, Fraunhofer turned his instrument toward the stars, the light of which he also examined, so that he may be justly called the inventor of stellar spectrum analysis. It is not to the credit of modern science that from this time forward spectrum analysis did not become a recognized branch of scientific inquiry, but as a matter of fact Fraunhofer's observations were buried in oblivion for nearly half a century. The importance of them was not recognized till the origin of the dark lines, both in sun and stars, had been explained by Stokes and others, as before stated. The lines in the solar spectrum were mapped with great diligence by Kirchhoff in 1861 and 1862, and later by Angström and Thalen, and this was done side by side with chemical work in the laboratory. The chemistry of the sun was thus to a great extent revealed. It was no longer a habitable globe, but one with its visible boundary at a fierce heat, surrounded by an atmosphere of metallic vapors, chief among them iron, also in a state of incandescence. To these metallic vapors Angström added hydrogen shortly afterwards.

Here, then, was established a firm link between the heavens and the earth; the first step to the problem of the chemistry of space had been taken.

It was only natural that as advances were made the instrumental equipment should keep pace with them. Spectroscopes were built on a larger scale; more prisms, which meant greater disperson, were employed to render the measurements of the lines in spectra more accurate. The growth of our knowledge especially necessitated the making of maps of the lines in the solar spectrum, and in the spectra of the chemical elements which had been compared with it on a natural scale. This was done by Angström, who utilized for this purpose the diffraction grating invented by Fraunhofer, and defined the position of all lines in spectra by their "wave lengths," in ten-millionths of a millimeter or "tenth-meters."

In 1862 Rutherfurd extended Fraunhofer's work on the stars by a first attempt at classification. Two years later Huggins and Miller produced maps of the spectra of some stars. Donati demonstrated that comets gave radiation spectra and Huggins did the same for nebulæ.

By these observations comets and nebulæ were shown to be spectroscopically different from stars, which at that time were studied by their dark lines only.

Chiefly by the labors of Pickering, the energetic head of the Harvard Observatory, science has been enriched during the later years by observations of thousands of stellar spectra, the study of which has brought about the most marvelous advance in our knowledge.

These priceless data have enabled us now to classify the stars not only by their brightness, or their color, but by their chemistry.

Next to be chronicled is the application of the so-called Doppler-Fizeau principle, which teaches us that when a light source is approaching or receding from us the light waves are crushed together or drawn out, so that the wave length is changed. The amount of change gives us the velocity of approach or recess, so that the rate of movement of stars toward or from the earth, or the uprush or downrush of the solar vapors on the sun's disk, can be accurately determined. A further utilization of this principle is found when the stars are so close together that they appear as one if the plane of motion passes near the earth. A line common to the spectra of both stars will appear double, twice in each revolution, when the motion to or from the earth, or, as it is termed, "in the line of sight," is greatest. "Spectroscopic doubles," as these stars are called, yield up many of their secrets which otherwise would elude us. Their time of revolution, the size of the orbit, and the combined mass can be determined.

To return from the stars to the sun.

By the device of throwing an image of the sun on the slit of the spectroscope the spectra of solar spots have been studied from 1866 onward, and a little later the brighter portions of the sun's outer envelopes, revealed till then only during eclipses, were brought within our ken spectroscopically so that they are now studied every day.

CELESTIAL PHOTOGRAPHY.

Wedgewood and Davy, in 1802, made prints on paper by means of silver salts, but it was not until 1830 that Niepce and Daguerre founded photography, which Arago, in an address to the French Chamber, at once suggested might subsequently be used to record the positions of stars.

In 1839 we find Sir John Herschel carrying out a series of experiments so important for our correct knowledge of the sequence of steps in the early stages of photography that I have no hesitation in quoting from one of Herschel's manuscripts relating to a deposit on a glass plate of "muriate" [chloride] of silver from a mixed solution of the nitrate with common salt. The manuscript states: "After forty-eight hours [the choride] had formed a film firm enough to bear draining the water off very slowly by a syphon. Having dried it, I found that it was very little affected by light, and by washing it with nitrate of silver, weak, and drying it, it became highly sensitive. In this state I took a camera picture of the telescope on it."

The original of the above-mentioned photograph, the first photograph ever taken on glass, is now in the science collection at the Victoria and Albert Museum, South Kensington.

In the early days of photography colored glasses were first used to investigate the action of different colors on the photographic plate. Sir John Herschel was among the first to propose that such investigations should be made direct with a spectrum, and he, like Dr. J. W. Draper, stated that he had found a new kind of light beyond the blue end of the spectrum, as the photographic plate showed a portion of the spectrum there which was not visible to the eye. Advance followed advance and in 1842 Becquerel photographed the whole solar spectrum, in colors, with nearly all the lines registered by the hand and eye of Fraunhofer, not only the blue end, but the complete spectrum from Draper's "latent light," as he called the ultra violet rays, to the extreme red end.

The first photograph of a celestial object was one of the moon secured by Dr. J. W. Draper in 1840; we had to wait until 1845, so far as I know, before a daguerreotype was taken of the sun; this was done by Foucault and Fizeau, while the first photograph of a star—Vega—was taken at Harvard in 1850. After the introduction of the wet collodion process regular photographs of the sun's surface were commenced, at Sir John Herschel's recommendation, at Kew, in 1858, and the total solar eclipse of 1860 was made memorable by the photographs of De La Rue, who before that time had secured most admirable photographs of the moon, as also had Rutherfurd.

Photography now began to pay the debt she owed to spectrum analysis.

The first laboratory photograph of the spectra of the chemical elements was taken by Dr. W. A. Miller in 1862.

Rutherfurd was the first to secure a photograph of the solar spectrum with considerable dispersion by means of prisms.

In 1863 Mascart undertook a complete photographic investigation of the ultra violet portion of the solar spectrum, a work of no mean magnitude. He, however, did not employ a train of prisms for producing the spectrum, but a defraction grating, using the light reflected from the first surface. The first photograph of the spectrum of a star was secured by Henry Draper, the son of Dr. J. W. Draper, one of the pioneers in photography, in 1872.

It was not till the introduction of dry plates in 1876 that the photography of the fainter celestial objects or of their spectra was possible, as a long exposure was naturally required. Stellar spectra were photographed by Huggins in 1879 and in the next year Draper photographed the nebula of Orion. As the dry plates became more rapid and as longer exposures were employed, revelation followed revelation; the nebulæ as seen by the naked eye, and even some stars, were found by the Henrys, Roberts, Max Wolf, Barnard, and others to be but the brighter kernels of large nebulous patches.

This new application of photography, depending upon long exposures (the longest one I know of has extended to forty hours), had an important reflex action on the mechanical parts of the telescope; it was not only necessary to keep the faintest star exactly on the same part of the plate during the whole of the exposure, but night after night the stellar image must be brought onto the same part of the plate so that the exposure might be continued.

A system of electric control of the going of the driving clock of the telescope by means of a sidereal clock was introduced, the simplest one being designed by Russell of Sydney, a most elaborate one by Grubb of Dublin.

Another application of the method of long exposures has been the discovery of minor planets by the trails impressed by their motion among the stars on the photographic plates on which the images of both are impressed.

A complete spectroscopic survey of the stars by means of photography was commenced in 1886 at Harvard College, as a memorial to Draper, who died while he was laboring diligently and successfully in securing advances in astrophysical inquiries. To carry on this work at Harvard, Professor Pickering wisely reverted to the method first employed by Fraunhofer and utilized by Respighi and another in 1871, of placing prisms in front of the object glass.

In the photographing of stellar spectra by means of objective prisms the driving clock of the telescope must not go exactly at sidereal rate, but at certain speeds, depending on the brightness and position of the star under examination.

This is necessary because the image of the spectrum of a star on the photograph is only a thin line in which it is impossible to see the spectral lines. The spectrum must be broadened, and this is accomplished by making the star image "trail" to a certain degree on the plate. This trailing is accomplished by means of the clock, the rate of which is made to vary. In this way the trail of a spectrum of a star on the photographic plate is always obtained of the same width, while the density of the image is made fairly constant by increasing the rate for bright stars and decreasing it for fainter ones. In this way spectra of the brighter stars, rivaling in perfection and detail those obtained of the spectrum of the sun itself thirty years ago, have been obtained. Such photographs have rendered a minute chemical classification of the stars possible.

One of the most interesting applications of photography to spectrum analysis during the latter part of the century has been the utilization by Messrs. Deslandres and Hale of a suggestion made by Janssen, that by employing photography images of the sun and its surroundings can be obtained in light on one wave length. In this way we can study the distribution of any one of the chemical constituents of the sun separately and note its behavior, not only on the sun itself, but in the atmosphere which enfolds the disk.

It is strange that, in spite of the suggestion of Faye and others after him, one of the great advantages of the employment of photography in astronomical work, namely, the abolition of "personal equation," has so far been almost entirely neglected. What "personal equation" is can be perhaps illustrated by considering an observer who is observing the transit of a star over the wires in a transit instrument.

His object is to note the exact time, to a fraction of a second, when a star passes each wire, and this is done by listening to the beats of a clock near at hand and estimating the fractions. Some observers constantly note the time either a little in advance or a little later than the actual time, and this small distance between the observer and the true times is more or less constant for each observer. This difference has to be taken into account for every observation. Even the use of the chronograph in transit work, by which the observation is electrically recorded, does not entirely eliminate the error. The photographic method of transit work has been experimented on, but so far as I know it has not yet been used at more than one or two observatories. It will doubtless eventually rid us of "personal equation" entirely, for the star image may be photographed and the time recorded by the same current of electricity.

At the end of the century we may almost say that, except in relation to the work of the meridional observatories, photographic methods of recording observations are becoming exclusively used. One of the cases in which its utility is most in evidence is in the matter of eclipse observations. Spectra of the sun's surroundings containing a thousand lines are taken in a second of time, thus replacing five or six doubtful eye observations by wealth of results, which have enabled the recent vast progress to be secured.

CATALOGUES.

Catalogues of the stars were among the first scientific records started by man, and so long as only the naked eye was used the work was not difficult, as only approximate positions were attempted, even by Hipparchus; but long before the eighteenth century dawned the problem was entirely changed by the invention of the telescope and by the provision of accurately divided circles; not only could better positions be recorded, but the number of stars to be catalogued was enormously increased, and furthermore other objects—nebulæ—presented themselves in considerable numbers.

In 1801 the star catalogues chiefly relied on were those of Lacaille, containing about 3,000 stars scattered over the whole heavens.

Maskelyne, who was then astronomer royal, had published in 1790 a catalogue of thirty-six fundamental stars, chiefly for the purposes of navigation. The first great catalogue of the century was the Fundamenta Astronomiæ of Bessel, produced in 1818. This contained 3,222 stars. The Bonn "Durchmüsterung," with its catalogue of 324,198 stars in the northern hemisphere and the corresponding atlas published in 1857–1863, was the next memorable achievement in this direction. For it we have to thank Bessel and Argelander and a perfect system of work.

Another monumental catalogue dealing with the stars in the southern heavens has been that of the southern stars observed by Gould

(1866). While the century is closing another catalogue far more stupendous than anything which could be conceived possible a few years ago is steadily being compiled. This we owe to the farsightedness and energy of Admiral Mouchez, a late director of the Paris Observatory. The work was commenced in 1892.

The whole heavens, north and south alike, have been divided into zones, and the chief observatories on the earth's surface are busy night after night in taking photographs of that part intrusted to them. The whole heavens are thus being made to write their autobiography, and the total gain to the astronomy of the future of this most priceless record can perhaps be scarcely grasped as yet, although the advantage of being able at any point of future time to see on a photographic plate what the heavens are telling now is sufficiently obvious.

Catalogues of the stars have, of course, led to other minor catalogues of various classes of stars, binary, variable, and the like. In the later years catalogues of stars, according to their spectra, have enriched science.

The first extensive catalogue of stella spectra was published by Vogel. It dealt with 4,051 stars, and appeared in 1883. It has since been followed by the Draper catalogue, based upon photographs of the spectra, which contains a much larger number. With regard to nebulæ Herschel published his third catalogue in 1802. The last catalogue of this nature is by Dreyer (1888), and contains 7,840 of these objects. In the time of Tycho they could be counted on the fingers of one hand.

INVESTIGATIONS OF SOME IMPORTANT ASTRONOMICAL CONSTANTS.

The century has been fruitful in the determination of many numerical values which are all important in enabling us to determine the distance and masses of the heavenly bodies, thereby giving us a firm grasp not only of the dimensions of our own system, but of those scattered in the celestial spaces.

To take the distances first. We must begin with the exact measure of the earth; for this we must measure the exact length of an arc of meridian or of parallel; that is, a stretch of the earth's surface lying north or south or east and west, between places of which the latitudes are accurately known in the former case and the longitude in the latter. In either case we can determine the number of miles which go to a degree. Beginning at the opening of the century with an arc of meridian of 2 degrees measured by Gauss from Göttingen to Altona, the arcs of meridian have grown longer as the century has grown older, till, at the close, the measurement of an arc of meridian from the Cape to Cairo, embracing something like 68 degrees of latitude, is being mooted.

The measurements of arcs of parallel have been developed by the rapid extension of telegraphic communications which now permit the longitude of the terminal stations to be determined with the greatest accuracy.

Thanks to this work we now have the size of our planet to a few miles. The polar diameter is 41,709,790 feet; but the equator is not a circle, the equatorial diameter from longitude 8° 15′ west to longitude 188° 15′ west is 41,853,258 feet; that at right angles to it is 41,850,210 feet; that is, some thousand yards shorter. The earth, then, is shaped like an orange slightly squeezed.

Knowing the earth's diameter, we can obtain the sun's distance by several methods—the old one by observing transits of Venus, one of which Cooke went out to observe in 1769, and two of which recurred in 1874 and 1882; new ones by observations of Mars or one of the minor planets at a favorable opposition, and by determining the velocity of light.

The recent discovery of a minor planet, "Eros,"[1] which in one part of its orbit is nearer the earth than Mars, has recently revived interest in this method and a combined attack is in contemplation.

It has been long known that light has a finite velocity; but we had to wait till the sixties before Fizeau and Foucault showed us how to determine its exact value. The methods introduced by them have been recently applied by Cornu, Newcomb, and Michelson, and the resulting value is slightly less than 300,000 meters per second. Combining this with the constant of aberration, the distance of the sun can be determined.

It is wonderful how these vastly different methods agree in the resulting mean distance. At the beginning of the century it stood roughly at 95,000,000 miles; this has been reduced to 93,965,000 miles. The extreme difference between the old and new values of the solar parallax, two-fifths of a second of arc, is represented by the apparent breadth of a human hair viewed at a distance of about 125 feet.

Knowing the distance of the sun, the way is open to us to determine, by a method suggested by Galileo, the distances of those stars which occupy a different position among their fellows, as seen from opposite points in the earth's orbit round the sun, points 186,000,000 miles apart. We now know the distances of many such stars, Bessel having determined the first in 1838. The nearest star to us, so far as we know, is Centauri, the light of which takes four and a half years to reach us. Not many years ago Pritchard applied photography to this branch of inquiry. We may therefore expect a still more rapid progress in the future.

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[1] [Dr. E. von Oppolzer gives the remarkable announcement of a variation of the brightness of Eros of about one magnitude, the change taking place in a few hours.—Nature LXIII, 1901, page 383.]

With regard to masses: We naturally must first know that of the earth; having its size, if we can determine its density, the rest follows.

The problem of determining the mean density of the earth has occupied the minds of many workers during the closing century. Newton (about 1728) pointed out how it could be deduced by observing the deviation from the vertical of a plumb line suspended near a large mass of matter—a mountain—the volume and density of which could be previously determined. This method, which is very laborious and requires the greatest skill and most delicate instruments, has been employed several times—by Bouguer and Condamine in 1738 at Chimborazo; Maskelyne in 1774 at Schehallien, in Scotland, and James at Arthur's Seat, near Edinburgh.

At the beginning of the century another method was introduced by Cavendish. This consists in measuring the attraction of two large spheres of known size and mass, such as two balls of lead on two very small and light spheres, by means of a torsion balance constructed by Mitchell for this purpose.

The most recent determination by this method, and one which is considered to give us perhaps the most accurate value, is that which is due to the skill and ingenuity of Professor Boys. His improvement consisted in constructing a most delicate torsion balance. The attracted spheres consisted of small gold balls suspended by a quartz fiber carrying a mirror to indicate the amount of twist. The whole instrument was quite small and could easily be protected from air currents and changes of temperature, while the use of the quartz fibers reduced to a minimum one of the greatest difficulties of the Cavendish experiment. The value of the mean density of the earth is now considered to be 5.6, which means that if we have a globe of water exactly the same size as our own earth the real earth would weigh just 5.6 times this globe of water. The earth's weight in tons does not convey much idea, but that it is six thousand trillions may interest the curious. This determination has enabled the masses of the sun, moon, planets, and satellites, and many sidereal systems to be accurately known in relation to the mass of the earth.

SOME ACHIEVEMENTS OF MATHEMATICAL ANALYSIS.

Uranus, a planet unknown to the ancients, was discovered by its movement among the stars by William Herschel in 1781. It was not until 1846 that another major planet was added to the solar system, and this discovery was one of the sensations of the century.

The story of the independent discovery of Neptune by Adams and Le Verrier, who were both driven to the conclusion that certain apparent irregularities in the motion of Uranus were due to the attraction of another body traveling on an orbit outside it, has been often told. The subsequent discovery of the external body not far from the place at which their mathematical analysis had led them to believe it would be seen will forever be regarded as a fine triumph of the human intellect.

But the results of the inquiries which now concern us are generally of not so sensational a character, although they lie at the root of our knowledge of celestial motions. They more often take the shape of tables and discussions relating to the movements of the bodies which make up our solar system.

Gauss may be said to have led the way during the present century by his *Theoria motus corporum cœlestium solem ambientium.* This was a worthy sequel to the Mechanique Celeste, in which work, toward the end of the preceding century, Laplace had enshrined all that was known on the planetary results of gravitation.

In later years Le Verrier and Newcomb have been among the chief workers on whom the mantle of such distinguished predecessors has fallen. From them the planet and satellite tables now in use have been derived.

But the motion of our own satellite, the moon, has had fascinations for other analysts besides those we have named.

The problem, indeed, of the moon's motion is one of the most difficult, and has taxed the ingenuity of astronomers from an early date. Even at the present day it is impossible to predict the exact position of the moon at any one moment, owing to inequalities and perturbations the exact varying values of which are not known.

The two most important theories of the motion of the moon, completed toward the middle of the century, were due to Hansen and Delaunay. The former's appeared in 1838, the lunar tables being published later (1857), while the latter's was published in 1860.

Hansen's theory had for its chief object the formation of tables. To avoid the inconvenience of using in his calculations series which slowly converge he inserted numerical values throughout. In Hansen's solution the problem is one actually presented by nature, allowance being made for every known cause of disturbance. There is one disadvantage, namely, that should observations demand a change in any of the constants used there is no means of making any correction in the results.

Delaunay's theory surmounted this difficulty, but at the expense of still greater inconvenience for making an ephemeris. The slow convergence of certain series involved an immense amount of labor to give sufficiently approximate results.

More recently, as the century is closing, Dr. Brown has taken up the subject and made a fresh attempt to calculate the motion of our satellite. It may be stated that he adopts all Delaunay's modifications of the problem and works them out algebraically; but there are many technical differences which it would be out of place to mention here.

Enough has been stated to show that there is not likely to be any breach of continuity in the treatment of this most important problem.

Another attack on the moon, and incidentally its motion, has recently been made by another analyst—Prof. George Darwin. Grappling with all the consequences of tidal friction, he has been able to present to us the past and future history of our satellite. Beginning as a part of the material congeries from which subsequently, some 50,000,000 years ago, both earth and moon, as separate bodies, were formed, it has ever since been extending its orbit, and so retreating farther away from its center of motion, while the period of the earth's rotation has been increasing at the same time from a possible period of some three hours when the moon was born to one of 1,400 hours when the day and month will be equal, something like 150,000,000 years being required for the process.

STELLAR EVOLUTION.

It was only in the eighties, after thousands of observations of the spectra of stars, nebulæ, and comets had been secured, that the full meaning of the revelations of the spectroscope began to dawn upon the world.

Before the introduction of spectrum analysis all stars were supposed to be suns, and the only difference recognized among them was one of brilliancy, and the variation of brilliancy in the case of some of them.

It ultimately came out that great classes might be recognized by the differences of their spectra, which were ultimately traced to differences in their chemistry and in their temperature, as determined by the extension of the spectra in the ultraviolet, the whiter stars being hotter than the red ones, as a white-hot poker is hotter than a red-hot poker.

Next there was evidence to show that a large proportion of the stars were not stars at all like the sun, but swarms of meteorites; and in this way the mysterious new stars which appear from time to time in the heavens, and a large number of variable stars, were explained as arising from collisions among such swarms.

The inquiry which dealt with the spectroscopic results, having thus introduced the ideas of meteor swarms and collisions to explain many stellar phenomena, went further and showed that the various chemical changes observed in passing from star to star might also be explained by supposing the whole stellar constitution to arise from cool meteoritic swarms represented by nebulæ, the changes up to a certain point being explained by a rise of temperature due to condensation toward a center. Here the new view was opposed to that of Laplace, advanced during the last century, that the stars were produced by condensation and cooling; but Kelvin had shown, before the new view was enunciated, that Laplace's view was contrary to thermodynamics, a branch of science which had developed since Laplace published his famous Exposition du Système du Monde.

After all the meteorites in the parent swarm had been condensed into the central gaseous mass that mass had to cool. So that we had in the heavens not only stars more or less meteoritic in structure, of rising temperature, but stars chiefly gaseous, of falling temperature. It was obvious that representatives of both these classes of stars might have nearly the same mean effective temperature and therefore more or less the same spectrum. A minute inquiry entirely justified these conclusions.

So far has the detailed chemistry of the stars been carried in the latter years of the century that the question of stellar evolution has given rise to that of inorganic evolution generally, the sequence in the phenomena of which can only be studied in the stars, for laboratory work without stint has shown that in them we have celestial furnaces, the heat of which transcends that of our most powerful electric sparks. In this way astronomy is paying the debt she owes to chemistry.

THE SUN AND HIS SYSTEM.

Although the outer confines of space have, as we have seen, been compelled to bring their tribute of new knowledge by means of the penetrating power possessed by modern telescopes, and the camera and spectroscopes attached to them, the study of the near has by no means been neglected, and for the reason that in astronomy especially we must content ourselves in the case of the more distant bodies by surmising what happens in them from the facts gathered in the region where alone detailed observations are possible.

Thus what we can learn about the sun helps to explain what we discern much more dimly in the case of stars. A study of the moon's face we are compelled to take as showing us the possibilities relating to the surface condition of other satellites so far removed from us that they only appear as points of light.

To begin, then, with the sun. Where a volume might be written a few words must suffice. I have already stated that at the beginning of the century the prevailing opinion was that it was a habitable globe. It was limited to the fiery ball we see. At the end of the century it is a body of the fiercest heat, and the ball we see is only a central portion of a huge and terribly interesting mechanism, the outer portions of which heave and throb every eleven years. Spots, prominences, corona, everything, feel this throbbing.

Although the discovery of spots on the sun was among Galileo's first achievements, it was reserved for the last half of the present century to demonstrate their almost perfect periodicity.

Thanks to the labors of Schwabe, Wolf, Carrington, and De la Rue, Stewart and Loewy, we now know that every eleven years the spots wax and wane. Tacchina and Ricco, during the last thirty years, have proved that the prominences follow suit, and the fact that the corona also obeys the same law was established during the American eclipse of 1878.

The study of solar physics consists in watching and recording the thermal, chemical, and other changes which accompany this period. Some of these effects can be best studied during those times when the ball itself is covered by the moon in an eclipse. Then the outer portions of the sun are revealed in all their beauty and majesty, and all the world goes to see.

But it is the quiet daily work in the laboratory which has enabled us to study the sun's place in relation to the other stars, and so to found a chemical classification of all the stars that shine.

From the sun we may pass to his system, and first consider the nearest body to us—the moon.

While some astronomers have been discussing the movements and evolution of our satellite, others have been engaged upon maps of its surface, upon questions dealing with a lunar atmosphere, or a study of the origin of the present conformations and of possible changes. The science of selenology may be said to have been founded by Schröter at the beginning of the century, but it required the application of photography in later years to put it on a firm basis. Maps of the moon have been prepared by Lohrmann, Beer and Mädler, and Schmidt, the latter showing the positions of more than 30,000 craters.

Very erroneous notions are held by some as to what we may hope to do in the examination of the moon's surface by a powerful telescope. A power of a thousand enables us to see it as if we were looking at York from London. It is recorded that Lassell once said that with his largest reflector in a "fit" of the finest definition he thought he might be able to detect whether a carpet as large as Lincoln's Inn Fields was round or square. Under these circumstances, then, we may well understand that the question of changes on the surface has been raised from time to time never to be absolutely settled one way or the other. By many the existence of an atmosphere is denied, and this is a condition which would negative changes, anything like the geological changes brought about on the surface of the earth, but the idea is now held by many that there is still an atmosphere, though of great tenuity.

The last few years of the century have been rendered memorable from the lunar point of view by the publication and minute study of a most admirable series of photographs of the moon obtained by the great equatorial Coudé of the Paris Observatory by Loewy and Puiseaux. One of the chief points aimed at has been to determine the sequence of the various events represented by the rilles, craters, and walled plains, the mountain ranges and seas. This work is still in progress, the fourth part of the atlas being published in 1900; but enough has already appeared to indicate that the results of the inquiry when completed will be of the most important kind. The authors have already come to the conclusion that the lunar and terrestrial sea bottoms much resemble each other, inasmuch as both have convex surfaces. The lunar seas began by sinking of vast regions; the formidable volcanic eruptions of which the moon has been the scene have taken place in times equivalent to those labeled "recent" in geological parlance. There is evidence that the axis of the moon has undergone great displacements, and four great periods of change have been made out. Finally they state that there is serious ground to believe that there is an atmosphere of some sort remaining.

It may readily be understood that with each increase of optical power new satellites of the various planets have been discovered. Soon after the discovery of Neptune a satellite was noted by Lassell. In 1846 both he and the eagle-eyed observer Dawes independently discovered another satellite (Hyperion) of Saturn. Lassell was rewarded in the next year by the discovery of two more satellites of Uranus; but, strangest observation of all, in 1877 Hall discovered at Washington two satellites of Mars some 6 or 7 miles only in diameter, one of them revolving round the planet in seven and one-half hours at a distance of less than 4,000 miles. As the day on Mars is not far different in duration from our own, this tiny satellite must rise in the west and south three times a day.

Wonderful as this discovery was, it is certainly not less wonderful when we consider it in connection with a passage in Gulliver's Travels, so true is it that truth is stranger than fiction. Swift, in his satirical reference to the inhabitants of Laputa, writes: "They have likewise discovered two lesser stars or satellites, which revolve round Mars, whereof the innermost is distant from the center of the primary planet exactly three of his diameters and the outermost five. The former revolves in the space of ten hours and the latter in twenty-one and a half."

The last discovery of this kind has been that of an inner satellite of Jupiter by Barnard in 1892.

The planets from Mercury to Saturn were known to the ancients. I have already referred to the discovery of Uranus by Herschel's giant telescope, not long before the century was born, and of Neptune, by analysis, toward the end of the first half of the century. With regard to what modern observations have done in regard to their physical appearance, the first place in general interest must be given to Saturn and Mars.

Saturn has always been regarded as the most interesting of the planetary family on account of its unique rings. Many subdivisions of the rings, and a dusky ring, first seen by Dawes and Bond, have been discovered during the last sixty years.

The meteoritic nature of the rings was suggested by Clerk Maxwell in 1857, and Keeler's demonstration of the truth of this view by means of the spectroscope, a few years ago, was brilliant in conception and execution.

But during the last half of the century the interest centered in Mars has been gradually increasing. The drawings made during the opposition of 1862, when compared with those made by Beer and Madler (1830–1840), made it perfectly clear that in this planet we had to deal with one strangely like our own in many respects. There were obviously land and water surfaces; the snow at the poles melted in the summer time; clouds were seen forming from time to time, and the changing tones of the water surfaces suggested fine and rough weather.

Afterwards came the revelation of the hawk-eyed Schiaparelli, beginning in the year 1877, and his wonderful map of the planet's surface. The land surfaces, instead of being unbroken, were cut up, as an English farm is cut up by hedges; straight lines of different breadths and tints crossed the land surfaces in all directions, and at times some of them appeared double. Schiaparelli naturally concluded that they were rivers—water channels—and, being an Italian, he used the appropriate word *canali*. This, unfortunately, as it turned out, was translated *canals*. Now canals are dug, *ergo* there were diggers. From this the demonstration not of the habitability, but of the actual habitation, of Mars was a small step, and the best way of signaling to newly found kinsmen across some 30,000,000 miles of space was discussed.

The world of science owes a debt of gratitude to Mr. Percival Lowell for having taken out to the pure air and low latitude of Arizona an 18-inch telescope for the sole purpose of accumulating facts tending to throw light upon this newly raised question. This he did in 1894. Schiaparelli has continued his magnificent observations through each opposition when the planet is most favorably situated for observation, and since 1896 Signor Cerulli, armed with a 15-inch Cooke, in the fine climate of Italy, has joined in the inquiry, so that facts are now being rapidly accumulated. It has been stated that markings similar to the strange so-called "canals" on Mars are to be seen on Mercury, Venus, and even on the satellites of Jupiter. Mr. Percival Lowell does not hesitate to proclaim himself in favor of their being due, in Mars, to an intelligent system of irrigation. Signor Cerulli claims that wherever seen they are mere optical effects. We may be well content to leave to the next century a general agreement on this interesting subject.

Finally, in our survey of our own system come comets and meteor swarms. One of the most fruitful discoveries of the century, that comets are meteor swarms, we owe to the genius of Schiaparelli,

A. H. Newton, and other workers on those tiny celestial messengers which give rise to the phenomena of "falling" or "shooting" stars.

The magnificent displays of 1799, 1833, 1866, and, alas, that which failed to come in 1899, we now know must be associated with Tempel's comet. This is by no means the only case so far established. The connection will in the future be closer still when the orbits of the various swarms observed throughout the year shall be better known.

Comets which attract public attention by their brightness and grandeur of form are rather rare, and, in fact, only twenty-five of such have been seen since 1800. We have, however, with the great advance in instrumental equipment, been able to discover many which are scarcely visible to the naked eye, and this has swollen the number of comets very considerably. In the seventeenth century we find that only thirty-two were observed, while in the eighteenth this number was more than doubled (seventy-two). This century more than three hundred have been placed on record, which is practically more than four times the number seen last century.

The last great comet visible any considerable time was that discovered by Donati in 1858 and so carefully observed by Bond. It is unfortunate that since the importance, in so many directions, of spectroscopic observations of comets has been recognized they have been conspicuous by their absence.

THE CONNECTION BETWEEN SOLAR AND TERRESTRIAL WEATHER.

Everybody agrees that all the energy utilized on this planet of ours, with the single exception of that supplied by the tides, comes from the sun. We are all familiar with the changes due to the earth's daily rotation, bringing us now on the side of our planet illuminated by the sun, then plunging us into darkness. That changes of season must necessarily follow from the earth's yearly journey round the sun is universally recognized.

On the other hand, it is a modern idea that those solar phenomena which prove to us considerable changes of temperature in the sun itself may, and, indeed, should, be echoed by changes on our planet, giving us thereby an eleven-year period to be considered as well as a year and a day.

This response of the earth to solar changes was first observed in the continuous records of those instruments which register for us the earth's magnetism at any one place. The magnetic effects were strongest when there were more spots, taking them as indicators of solar changes. Lamont first, without knowing it, made this out at the beginning of the latter half of the century (1851) from the Göttingen observations of the daily range of the declination needle. Sabine, the next year, not only announced the same cycle in the violence of the "magnetic storms" observed at Toronto, but at once attributed them to solar influence, the two cycles running concurrently. It is now universally recognized that terrestrial magnetic effects, including auroræ, minutely echo the solar changes.

The eleven-year period is not one to be neglected.

Next comes the inquiry in relation to meteorology. Sir William Herschel, in the first year of the century, when there were practically neither sun spot nor rainfall observations available, did not hesitate to attack the question whether the price of wheat was affected by the many or few spot solar condition. He found the price to be high when the sun was spotless, and vice versa.

By 1872, however, we had both rainfall and sun-spot observations, and the cycle of the latter had been made out. Meldrum, the most distinguished meteorologist living at the time, and others pronounced that the rainfall was greatest at sun-spot maximum, and, further, that the greatest number of cyclones occurred in the East and West Indies at such times.

This result with regard to rainfall was not generally accepted, but Chambers showed shortly afterwards an undoubted connection between the cycles of solar spots and barometric pressure in the Indian area.

By means of a study of the widened lines observed in sun spots an attempt has been recently made to study the temperature history of the sun since about 1877, and the years of mean temperature and when the heat was in excess (+) and defect (−) made out have been as follows:

HEAT CONDITION.

	Mean.	+Mean.	−Mean.	+Mean.	−Mean.
Years	1869	1876	1881	1886–87	1891–92
	1870–1875	1877–1880	1882–1886	1887–1891	1892

Having these solar data, the next thing to do was to study the Indian rainfall during the southwest monsoon for the years 1877–1886, the object being to endeavor to ascertain if the + and − temperature pulses in the sun were echoed by + and − pulses of rainfall. The Indian rainfall was taken first because in the Tropics the phenomena are known to be the simplest. It was found that in many parts of India the + and − conditions of solar temperature were accompanied by + and − pulses, producing pressure changes and heavy rains in the Indian Ocean and the surrounding land. These occurred generally in the first year following the mean condition; that is, in 1877–78 and 1882–83.

The rainfalls at Mauritius, Cape Town, and Batavia were next collated to see if the pulses felt in India were traceable in other regions surrounding the Indian Ocean to the south and east. This was found to be the case.

A wider inquiry was followed, we are told, with equal success, so that we are justified in hoping that the question of the dependence of terrestrial upon solar weather has made a step in advance.

But just as the general public and practical men took little heed of the connection between sun spots and magnetism until experience taught them that telegraphic messages often could not "get through" when there were many sun spots, so the same public will not consider the connection in regard to meteorology unless the forecasting of droughts and famines be possible.

The recent work suggests that if the recent advances in solar physics be considered, the inquiries regarding rainfall may be placed on a firmer basis than they could possibly have had in 1872 and that such forecastings may become possible.

What was looked for in 1872 was a change in the quantity of rain at maximum sun spots only, the idea being that there might be an effective change of solar temperature, either in excess or defect, at such times, and that there would be a gradual and continuous variation from maximum to maximum.

We see that the rainfalls referred to above justify the conclusions derived from the recent work that two effects ought to be expected in a sun-spot cycle instead of one. There was excess of rainfall, not only near the sun-spot maximum, but near the minimum.

If the authors of this communication to which I refer are right, then droughts and famines occur in India because the rain pulses, which are associated with the solar heat pulses, are of short duration. When they cease, the quantity of rain which falls in the Indian area is not sufficient, without water storage, for the purposes of agriculture. They are followed, therefore, by droughts, and at times subsequently by famines. They divide the period 1877–1889 as under:

Rain from − pulse	1877. 1878. 1879 (part).
No rain pulse	1879 (part). 1880 (central year). 1881 (part).
Rain from + pulse	1881 (part). 1882. 1883. 1884 (part).
No rain pulse	1884 (part). 1885 } (central years). 1886 } 1887 (part).
Rain from − pulse	1887 (part). 1888. 1889.

Their statement is based on the fact that all the famines which have devastated India for the last seventy years have occurred at intervals of eleven years or thereabouts, working backward and forward from the central years 1880 and 1885–86 in the above table, the middle years, that is, between the pulses.

Mr. Willcocks, in a paper read at the Meteorological Congress at Chicago, remarked that "famines in India are generally years of low flood in Egypt."

It is now pointed out that the highest Niles follow the years of the + and − pulses, as does the highest rainfall in the Indian area.

Even if these results, which were communicated to the Royal Society of London five weeks before the end of the century, be confirmed, it may be pointed out that Sir William Herschel's suggestion of 1801 will have required a whole century for its fulfillment, so slowly do those branches of science move which have not already led to some practical development.

A PRELIMINARY ACCOUNT OF THE SOLAR ECLIPSE OF MAY 28, 1900, AS OBSERVED BY THE SMITHSONIAN EXPEDITION.[1]

By S. P. LANGLEY.

Partly in deference to the report of the United States Weather Bureau, from which it appeared that the chance of a fair eastern sky on the morning of the eclipse was about 8 to 1, and after examination by Mr. Abbot of many stations in North Carolina, Wadesboro, of that State, was selected early in April as the site of the Smithsonian observations. The advantages of Wadesboro being also recognized by Professor Young, of Princeton, Professor Hale, of Yerkes Observatory, and the Rev. J. M. Bacon, of the British Astronomical Association, it came about that four large observing parties, besides several smaller ones and numerous excursionists from the surrounding country, were all joined to produce at Wadesboro one of the largest company of eclipse observers ever assembled for scientific purposes. It is a matter for congratulation that the sky at Wadesboro upon the day of the eclipse was cloudless and clearer than the average, so that the efforts of the observing forces were not thwarted by any circumstances beyond their control. The provisions of the mayor and authorities of Wadesboro for preventing intrusion before and during the eclipse, and thus securing an undisturbed field of operations, deserve especial recognition. Further than this, the many acts of courtesy and hospitality to the visiting astronomers on the part of the townspeople will long be remembered by the recipients.

The Smithsonian party proper consisted of thirteen observers, and included Mr. Langley, Mr. Abbot, aid acting in charge of the Smithsonian Astrophysical Observatory; Mr. Smillie, in charge of photography; Mr. Putnam, of the United States Coast Survey, Mr. Fowle, Mr. Mendenhall, Mr. Child, Mr. Draper, Mr. Gill, Mr. Kramer, and Mr. Smith. Included with these the Rev. Father Searle and the Rev. Father Woodman gave most valuable assistance. Mr. Hoxie, of Port Royal, S. C., and Mr. Little, of Wadesboro, rendered valued assistance to Mr. Putnam during totality.

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[1] Reprinted from Science, Vol. XI, No. 286, June 22, 1900.

Professor Hale, of the Yerkes Observatory, was a member of the party, while still in general charge of the Yerkes expedition, and his counsel and aid were of the greatest service. Mr. Clayton, of Blue Hill Meteorological Station, occupied a part of the grounds of the Smithsonian party.

The main object of the investigation was, of course, the corona, and of this (first) a photographic and visual study of its structure, with (second) a determination by the bolometer whether appreciable heat reaches us from it, and, if possible, an examination of the form of its spectrum energy curve.

The writer had been particularly struck, when observing the eclipse of 1878, on Pikes Peak, by the remarkable definiteness of filamentary structure close to the sun's limb, and had never found in any photographs, not even in the excellent ones of Campbell taken at the Indian eclipse of 1898, anything approaching what he saw in the few seconds which he was able to devote to visual observations at the height of 14,000 feet. His wish to examine this inner coronal region with a more powerful photographic telescope than any heretofore used upon it was gratified by the most valued loan, by Prof. E. C. Pickering, of the new 12-inch achromatic lens of 135 feet focus just obtained for the Harvard College Observatory. This lens, furnishing a focal image of more than 15-inch diameter, was mounted so as to give a horizontal beam from a coelostat clock-driven mirror by Brashear, of 18-inch aperture, and used with 30-inch square plates. To supplement this great instrument, a 5-inch lens of 38 feet focus, loaned by Professor Young, was pointed directly at the sun. This formed images upon 11 by 14 inch plates moved in the focus of the lens by a water clock. Specially equatorially mounted lenses of 6, 4, and 3 inch aperture, driven by clockwork, were provided for the study of the outer corona, and the search for possible intramercurial planets.

For the bolometric work the massive siderostat, with its 17-inch mirror, with a large part of the delicate adjuncts employed at the Smithsonian Institution in recent years to investigate the sun's spectrum, was transported to Wadesboro. The excessively sensitive galvanometer reached camp without injury even to its suspending fiber, a thread of quartz crystal one fifteen-thousandth of an inch in diameter.

Besides these two chief aims (the photography and bolometry of the inner corona), several other pieces of work were undertaken, including the automatic reproduction of the "flash spectrum" by means of an objective prism with the 135-foot focus; the photographic study of the outer coronal region, including provision for recognizing possible intramercurial planets, already alluded to, visual and photographic observations of times of contact, and sketches of the corona, both from telescopic and naked-eye observations.

The assignment of the observers was as follows: Mr. Langley, in general charge of the expedition, observed with the same 5-inch telescope used by him on Pikes Peak in 1878, which was most kindly lent for this special comparison by the United States Naval Observatory; C. G. Abbot, aid acting in immediate charge, assigned with C. E. Mendenhall to the bolometer; T. W. Smillie, having general direction of the photographic work, made exposures at the 135-foot telescope; F. E. Fowle, jr., assigned to 38-foot telescope; Father Searle, directing the assembled telescopes for the outer coronal region, and for intramercurial planets, assisted by P. A. Draper and C. W. B. Smith, exposed two cameras of 3-inch aperture and 11-foot focus, and two of 4½-inch aperture and 3½ feet focus; all four of these telescopes being mounted on a single polar axis driven by an excellent clock; De Lancey Gill, assisting Mr. Smillie, removed the flash spectrum objective prism at second contact, and made a single long exposure with a 6-inch photographic lens of 7½ feet focus equatorially mounted; Assistant G. R. Putnam, who, by the kindness of the Superintendent of the United States Coast Survey, was detailed for latitude,[1] longitude,[2] and time observations, also observed contacts, directed the striking of signals by Mr. Little, and rendered other valuable services. Mr. Putnam was assisted in recording contacts by Mr. Hoxie. R. C. Child, observing with a 6-inch telescope of 7½ feet focus, made sketches with special references to inner coronal detail, and was, in addition, charged with all electrical circuits for chronograph and automatic photographic apparatus. Father Woodman, with a 3½-inch telescope, observed contacts and made sketches.

The first detachment, consisting of Messrs. Abbott, Fowle, Kramer (instrument maker), and Smith (carpenter), reached Wadesboro May 4, and were soon joined by Messrs. Draper and Putnam. The latter returned to Washington after a short but satisfactory latitude and longitude campaign, reaching Wadesboro again just before the eclipse, Other members of the party reached camp on and after the middle of the month. The first comers found a very satisfactory shed already erected and piers begun. Not a day passed, from the time of the arrival of the apparatus, May 7, to the day before the eclipse, that was not fully occupied in perfecting the arrangements.

The most striking portion of the installation was the line beginning at the northwest pier, with its equatorial and cœlostat, continued from thence south of east by the two great diverging tubes of the 135-foot telescope and spectroscope. These tubes were covered with white canvas, presenting the appearance of two immensely prolonged A tents, ending beyond the photographic house, where the 38-foot telescope tube pointed east and upward at an angle of 42° with the horizon. When the equatorial, with its large special conical-tube camera, with

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[1] 34° 57′ 52″ N.

[2] $5^h\ 20^m\ 17.8^s$ W.

all this long branching extent of white canvas ending in the uplifted tube of the 38-foot telescope, was seen in the light of the moon, the extensive field, with its preparations, exhibited a still more picturesque scene than by day.

Less imposing, and perhaps more ungainly, was the combination of four great cameras under the main shed, designed to search for new planets and to depict the outer corona. These might well be described as like a cabin and an outbuilding, mounted on a polar axis, yet despite their awkward proportions they were made to follow very accurately.

The morning of the eclipse dawned cloudless and very fairly clear. Deep blue sky, such as the writer had seen on Pikes Peak, of course is not among the ordinary possibilities of an eclipse, but the milkiness of the blue was less pronounced than is usual in the summer season, and all felt that the seeing promised well.

At fifteen minutes before totality a series of rapid strokes on the bell called everyone to his post, and one minute before the expected contact five strokes were given as a final warning. Coincidently with the actual observation of the second contact by Mr. Putnam, the first of two strokes upon the bell sounded, and the work began. After eighty-two seconds (the duration of totality from the Nautical Almanac was ninety-two seconds) three strokes were given as a signal to stop the long photographic exposures. Scarcely more than five seconds after this the sun's crescent reappeared. The duration of totality as observed by Mr. Putnam was approximately eighty-eight seconds.

To visual observers the sky was notably not a dark one. No second magnitude stars were observed with the naked eye, and most of the on-lookers saw only Mercury conspicuously, though Venus was distinguished at a low altitude, and Capella also was seen. So high a degree of sky illumination can not but have operated unfavorably in the study of the outer corona or in the search for intramercurial planets, and this is to be remembered in connection with what follows.

BEFORE TOTALITY.

A deepened color in the sky, a fall of temperature, and a rising breeze were distinctly noticeable. No change in direction of the wind was noticed. Shadow bands were seen, but those who attempted to measure their velocity found them too rapid and flickering for any great exactness in this determination. There was tolerable unanimity among independent observers as to their size and distance apart (about 5 inches), though some thought this less as totality approached.

It was noticed that the birds grew silent just before and during totality, but, true to their nature, the English sparrows were last to be still and first to begin their discussion of the eclipse after the return of light.

DURING TOTALITY.

The attention of all visual observers was at once caught by the equatorial streamers. Father Woodman's comparison of the appearance to a structure of mother-of-pearl was generally recognized as good, but different observers differed on the color estimate. A yellowish-green tinge was noticed by the artist of the party, Mr. Child, while to others the light was straw-colored or golden.

The general coronal form, to the naked eye, was nearly that of the small annexed photograph, which, though taken by one of the smaller objectives, gives a good view of the relative intensities. The same extensions of the equatorial corona could be followed by the naked eye from 3 to 3½ solar diameters.

The visual telescopic observations of the writer gave little indication of the finely divided structure of the inner corona which he had noticed at Pikes Peak. Structure, to be sure, was evident, but not in such minute subdivision as had then been seen, and though one remarkable prominence as well as several smaller ones was visible, the coronal streamers did not give to the writer the impression of being connected with these prominences, though the relationship of some of them to the solar poles was abundantly manifest.

AFTER TOTALITY—RESULTS.

Comparing notes after totality, all observers reported a successful carrying out of the programme. The greatest interest centers in the direct coronal negatives taken with the 135-foot telescope. Mr. Smillie exposed six 30 by 30 inch plates during totality, with times ranging from one-half a second to sixteen seconds, and three others were exposed by him immediately after the third contact.

At this writing only a part of the negatives taken have been developed. Their general quality may be inferred from the examples here given, after due allowance for the great loss suffered by translation on to paper, even with the best care.[1]

Plate I is a view taken with one of the smaller objectives (6 inches), given here to afford the reader an idea of the general disposition of the coronal light. The upper part is the vertex in the inverted field.

Plate II is a portion of one of the great 15-inch circular images obtained with the 135-foot focus telescope. It was obtained in the great disk in the last exposure during totality of 8 seconds, showing one of the principal prominences then on the sun's disk, with a disposition of the lower filaments near it.

Plate III is a portion of the same set of plates, but taken with a sixteen-second exposure. The part near the sun has, of course, been

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[1] The illustrations here are later than those provided for Science, and are repeated here for the readers anew, though already given on pages 104, 105 of the Secretary's report in this volume, where others will be found.

intentionally over-exposed, in order to better exhibit the remarkable polar streamers, extending here to a distance of about six minutes from the sun, but still further in Mr. Child's telescopic drawing (not given).

Plate IV is a view of a small part of the apparatus on the field, including the terminus of the 135-foot horizontal tube with its canvas covering, which has been described as like an extended A tent. The photographic room is seen at the end of the tube and beyond that the tube containing the lens loaned by Professor Young, pointing directly skyward. In the immediate foreground is the 5-inch equatorial.

That it will be impracticable to give here all of the disk of the moon in the large photographs will be evident when it is considered that the lunar circumference on each plate is about 4 feet; but it will be inferred from the examples that the prominences and polar streamers, as well as their features, appear in imposing magnitude and detail.

Many of what it is hoped will be most interesting photographs still await development, but Mr. Smillie's thorough preparation is promising adequate results.

HEAT OF CORONA.

Mr. Abbot, with the aid of Mr. Mendenhall, appears to have measured the heat of the corona, and in spite of previous efforts this is probably the first time that it has been really shown to exist. For five minutes before second contact the bolometer was successfully exposed to the region of the sky close to the narrowing crescent of the sun where the corona was shortly to appear. A diaphragm was interposed in the beam having an aperture of only 0.4 square centimeter, and deflections rapidly diminishing from 80 to 6 millimeters were obtained, the last being about forty seconds before totality. Then the diaphragm was opened to 290 square centimeters and a negative deflection of 13 millimeters was observed after totality, where these positive deflections had just been found, showing that the corona was actually cooler than the background which had been used at the room temperature. Next the black surface of the moon was allowed to radiate upon the bolometer, and the still larger negative deflection of 18 millimeters was observed.[1]

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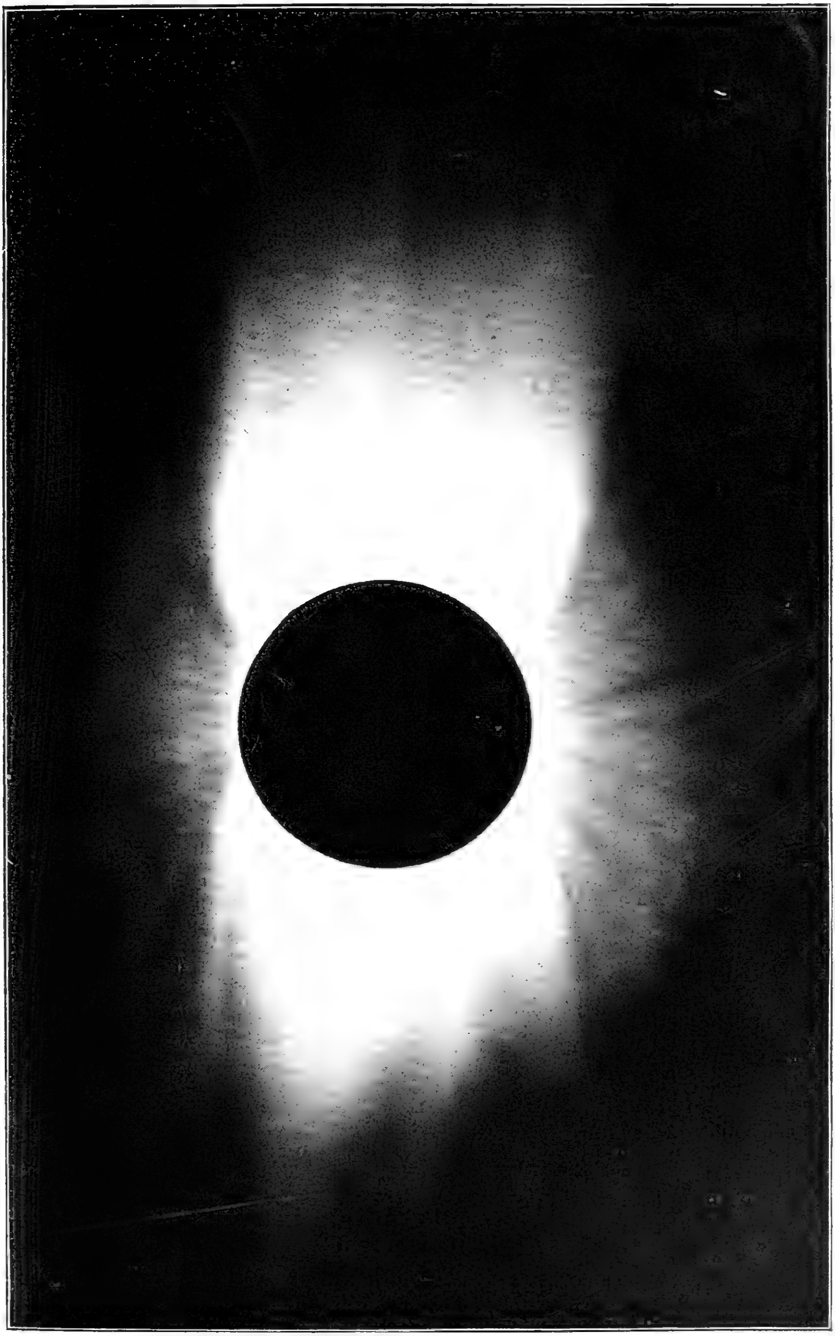
[1] Additional note, April, 1901.—It will be observed that three fundamental observations were taken, (1) on a screen of dark cardboard of the temperature of the bolometer; (2) on the dark body of the moon, and (3) on the inner corona. There was unfortunately not time to take a fourth on the sky near the corona, which was desirable though not indispensable.

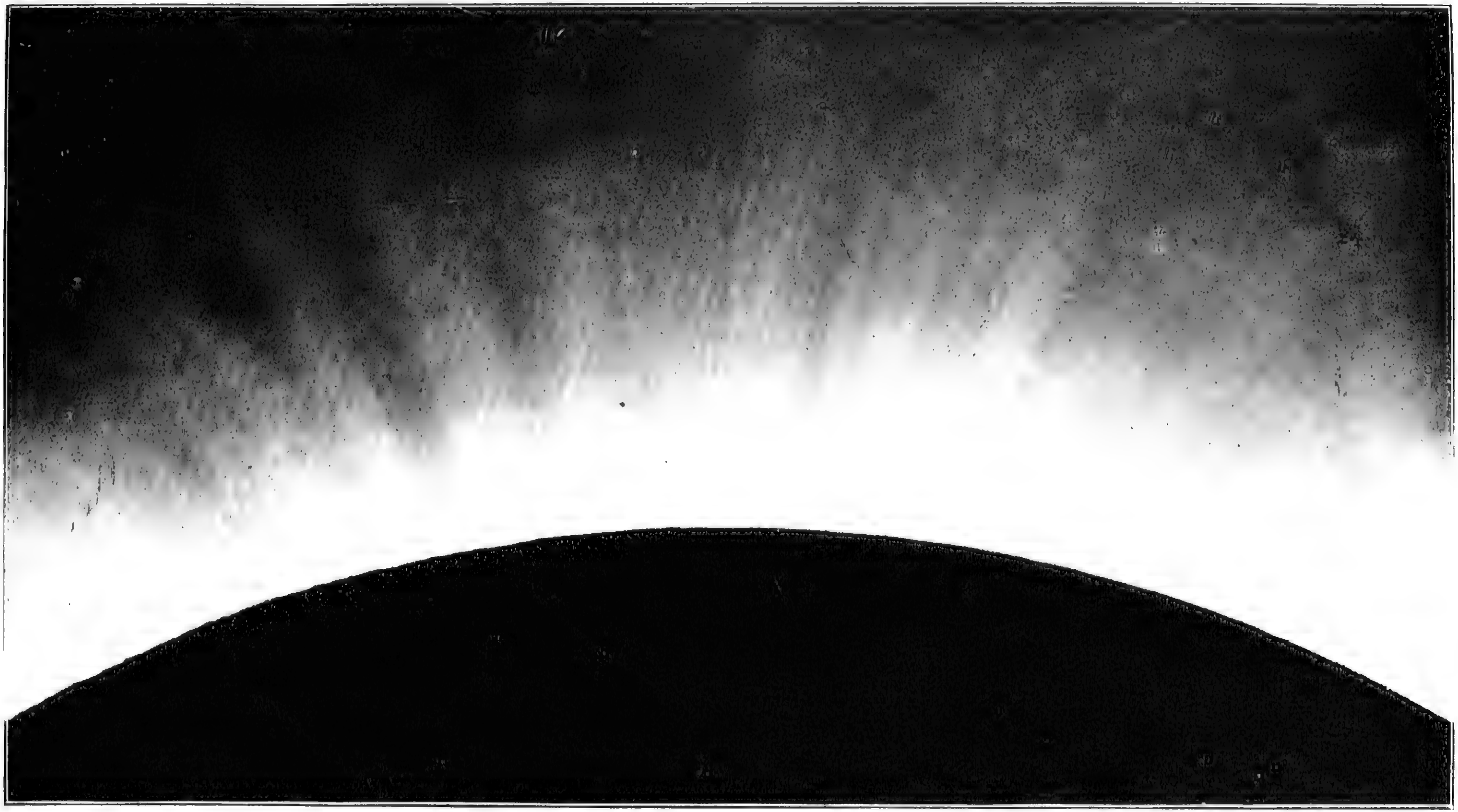
These three observations give the following readings: The one on the screen was arbitrary, and calling it zero, that on the dark moon was minus 18, and that on the inner corona was minus 13. The sky radiation during the last two in neighboring regions is taken as equal. The algebraically increased reading for the coronal radiation, then, was probably due to this radiation being superposed on that of the sky.

Since the eclipse the bolometer has been set on a screen of its own temperature,

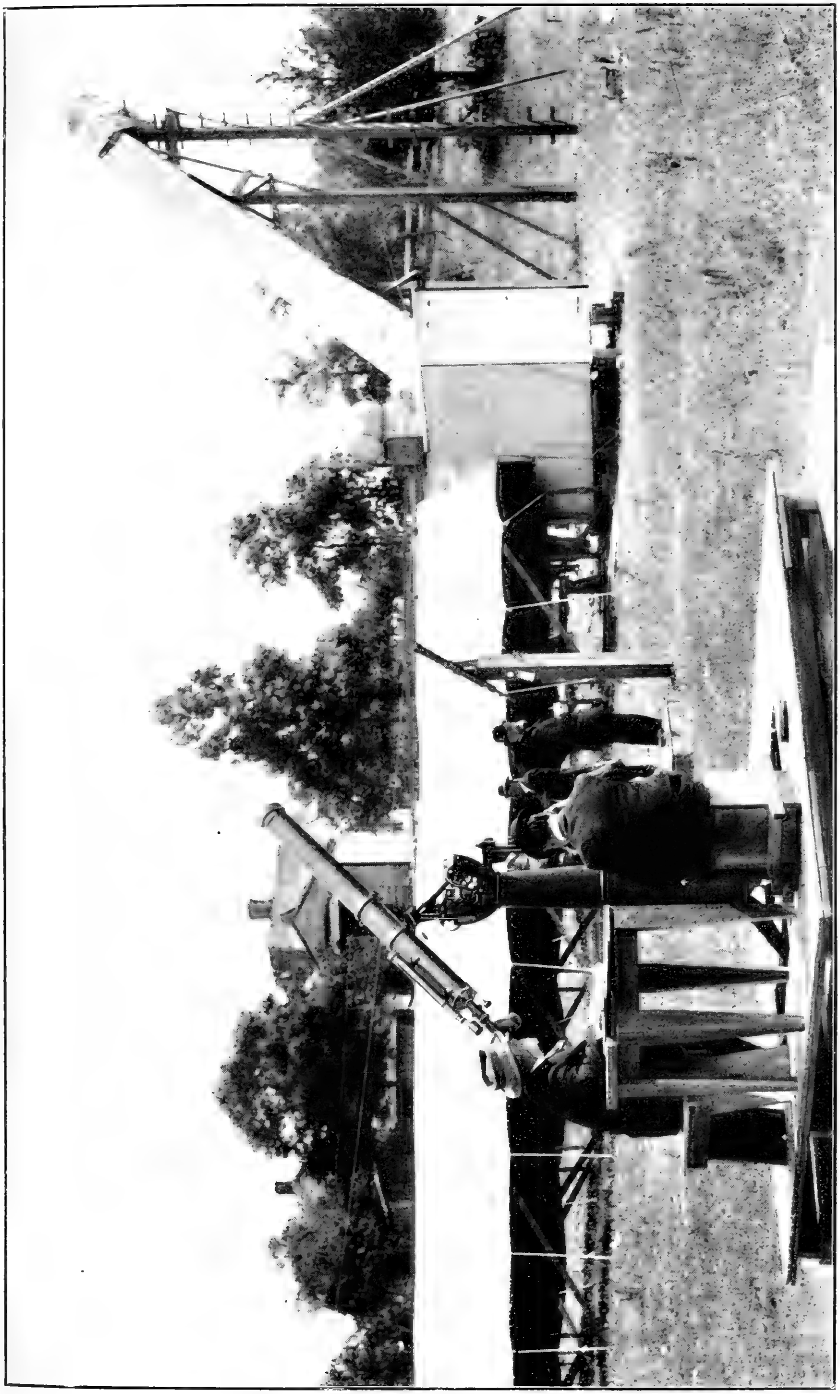


GENERAL VIEW OF THE CORONA.

PROMINENCE — [illegible] THE 150 FOOT FOCUS TELESCOPE



CENTRAL PART OF THE SUN'S POLAR STREAMER, SHOWN BY THE 135-FOOT FOCUS TELESCOPE.



THE 5-INCH EQUATORIAL.

The important result was that the corona gave a positive indication of heat as compared with the moon.

This heat, though certain, was, however, too slight to be subdivided by the dispersion of the prism with the means at hand.

The negatives taken to depict the outer corona show from three to four solar diameters extension for the longest streamers. The equatorial "wings" as they recede from the sun are finally lost in an illuminated sky, without any indication of having actually come to an end.

No attempt to carefully examine the plates taken for intramercurial planets has yet been possible. It is, however, as has been remarked, doubtful if very faint objects will be found, in consideration of the considerable sky illumination during totality. However, Pleione in the Pleiades (a star of the 6.3 magnitude) is plainly seen on one of the plates and some smaller ones are descernible.

On the whole, the expedition may be considered as promising to be very satisfactory in its results, and that it was so is largely owing not only to the efficient care of Mr. Abbot, but to the many gentlemen who have assisted me with the loan of valuable apparatus, with counsel, with voluntary service, and with painstaking observation, to one and all of whom I desire to express my obligations.

SMITHSONIAN INSTITUTION,
Washington, D. C., June 9, 1900.

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giving zero; on the bright moon, giving plus 55, and on the night sky near the moon, giving minus 30.

From my study of the visual photometric observations made at Pikes Peak in 1878 and at other places, it appears that the average visual brightness of the portion of the corona covering the bolometer at Wadesboro was approximately equal to that of the full moon.

We infer, then, that the full moon being of the average brightness of the observed portion of the inner corona, the bolometric effect of its visual radiation may be supposed to be equal to that of the corona, but the observations above recorded show that the total radiations from the moon being 50 plus 30, or 80 bolometric divisions, are 16 times as great as the radiations from the inner corona, being only 5 (i. e., $-13 + 18$) such divisions, and hence it may be supposed that the corona lacks that large amount of infrared radiation which is proper to the moon's spectrum.

The moon's spectrum, however, is that of a heated solid body, and all heated solid bodies, and heated gaseous bodies as well, send to the bolometer large amounts of infrared radiation. So far, then, we might conclude that the inner corona has not the radiations of a hot solid or gaseous body, but owing to the lack of a contemporary measure of the sky radiation just outside the corona, and of a full knowledge of the influences that the atmospheric radiations proper would have on our ability to discriminate this radiation, the above conclusions, though highly probable, are not presented as being absolutely final, and it is hoped to repeat them at the forthcoming eclipse in May, 1901. (S. P. L.)

NOTES ON MARS.

The following article by Sir Robert Ball, which appeared as long ago as 1893, is republished on account of its clear, untechnical statement of a proposed theoretical means for determining if Mars has or has not an atmosphere, which has been lately the subject of much discussion, for, since it appeared, this interesting theory of Mr. Johnstone Stoney has received different interpretations, and some of these are adverse to the belief in a Martian atmosphere.

It is, indeed, probable, from observation, that there is little atmosphere, or at least little like our own, and it is doubtful whether there is water or snow, but observations are not consistent, and the question must be considered as still debatable. The conclusions of Mr. Stoney, are not, however, universally accepted. For instance, Mr. Cook, in the Astrophysical Journal for January, 1900, using other assumptions, comes to the conclusion that, although Stoney's result for the moon may be true, that yet the earth and the major planets might not only retain an atmosphere of nitrogen and oxygen, but also of hydrogen and helium.—S. P. L.

I. Mars.[1]

By Sir Robert S. Ball, F. R. S.

* * * From one cause or another it happens that Mars is the most worldlike of all the other globes which come within the range of effective observation. It would, indeed, be very rash to assert that other bodies may not have a closer resemblance to our earth than Mars has, but of them we have either little knowledge, as in the case of Venus, or no knowledge at all. No doubt both Jupiter and Saturn can vie with Mars in the copiousness of detail with which they delight the astronomers who study them. These grand planets are deserving of every attention, but then the interest they excite is of a wholly different kind from that which makes a view of Mars so attractive. Jupiter offers us a meteorological study of the most astounding cloud system in creation. Saturn gives an illustration of a marvelous dynamical system, the like of which would never have been thought possible had it not actually presented

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[1] From Publications of the Astronomical Society of the Pacific, January 28, 1893, vol. 5, No. 28. Reprinted (with omissions) from Goldthwaite's Geographical Magazine for December, 1892.

itself to our notice. But the significance of Mars is essentially derived from those points of resemblance to the earth which are now engrossing attention. Mars is clearly a possible world, presenting both remarkable analogies and remarkable contrasts to our own world, and inducing us to put forth our utmost endeavors to utilize so exceptional an occasion as that presented in the close approach which it has now made. Let us see what we have learned about this globe.

In the first place, it should be noticed that Mars must be a small world in comparison with our own. The width of this globe is only 4,200 miles, so that its volume is but the seventh part of that of the earth. The weight of Mars is even less than what might have been expected from his bulk. It would take nearly ten globes, each as heavy as Mars, to form a weight equal to that of the earth. This fundamental difference in dimensions between Mars and our globe is intimately connected with certain points of contrast which it offers to the earth. Of these the most important is that which concerns the atmosphere. When we consider the qualification of a globe as a possible abode for organic beings, it is natural to inquire first into the presence or the absence of an atmosphere. Seeing that our earth is enveloped by so copious a shell of air, it follows that the beings which dwell upon its surface must be specially adapted to the conditions which the atmosphere imposes. Most, if not all, animals utilize this circumstance by obtaining a proximate source of energy in the union of oxygen from the atmosphere with oxidizable materials within their bodies. In this respect the atmosphere is of such fundamental importance that it is difficult for us to imagine what that type of life must be which would be fitted for the inhabitants of an airless globe. In other respects, which are hardly less important, the conditions of life are also dependent on the fact that we live at the bottom of an ocean of air. It is the atmosphere which, to a large extent, mitigates the fierceness with which the sun's rays would beat down on the globe if it were devoid of such protection. Again, at night, the atmospheric covering serves to screen us from the cold that would otherwise be the consequence of unrestricted radiation from the earth to space. It is, therefore, obvious that the absence of a copious atmosphere, though perhaps not absolutely incompatible with life of some kind, must still necessitate types of life of a wholly different character from those with which we are familiar. In attempting, therefore, to form an estimate of the probability of life on another world it is of essential importance to consider whether it possesses an atmosphere. * * *.

Modern research has demonstrated that what we call a gas is in truth a mighty host of molecules far too small to be perceptible by the most powerful microscope. Each of these molecules is animated by a rapid movement, which is only pursued for a short distance in one direction before a rencontre takes place with some other molecule, in consequence of which the directions and velocities of the individual molecules are continually changing. For each gas the molecules have, however, a certain average pace, which is appropriate to that gas for that temperature, and when two or more gases are blended, as in our atmosphere, then each molecule of the constituent gases continues to move with its own particular speed. Thus, in the case of the air, the molecules of ogygen, as well as the molecules of nitrogen, are each animated by their characteristic velocity, and the same may be said of the molecules of carbonic acid or of any other gas which in more or less abundance may happen to be diffused through our air. For two of the chief gases the average velocities of the molecules are as follows: Oxygen, a quarter of a mile per second; hydrogen, 1 mile a second; in each case the temperature is taken to be 64° C. below zero, being presumably that at the confines of the atmosphere. It will be noticed that there is a remarkable difference between the speeds of the two molecules here mentioned. That of hydrogen is by far the greatest of any gas.

We may now recall a fundamental fact in connection with any celestial body, large or small. It is well known that with the most powerful pieces of artillery that can be forged a projectile can be launched with a speed of about half a mile per second. If the cannon were pointed vertically upward, the projectile would soar to a great elevation, but its speed would gradually abate, and the summit of its journey would be duly reached, after which it would fall back again on the earth. Such would undoubtedly be the case if the experiment were made on a globe resembling our own in size and mass. But on a globe much smaller than the earth, not larger, for instance, than are some of the minor planets, it is certain that a projectile shot aloft from a great Armstrong gun would go up and up and would never return. The lessening gravitation of the body would fail to recall it. Of course we are here reminded of Jules Verne's famous Columbiad. According to that philosopher, if a cannon were pointed vertically and the projectile were discharged with a speed of 7 miles a second, it would soar aloft, and whether it went to the moon or not, it would at all events not return to the earth except by such a marvelous series of coincidences as those which he has described. But the story will, at all events, serve to illustrate the fact that for each particular globe there is a certain speed with which if a body leaves the globe it will not return.

It is a singular fact that hydrogen in its free state is absent from our atmosphere. Doubtless many explanations of a chemical nature might be offered, but the argument Dr. Stoney has brought forward is most interesting, inasmuch as it shows that the continued existence of hydrogen in our atmosphere would seem to be impossible. No doubt the average speed at which the molecules of this gas are hurrying about is only 1 mile a second, and therefore only a seventh of the critical velocity required to project a missile from the earth so as not to return. But the molecules are continually changing their velocity, and may sometimes attain a speed which is seven times as great as the average. Suppose, therefore, that a certain quantity of hydrogen were diffused through our air. Every now and then a molecule of hydrogen in its wandering would attain the upper limit of our atmosphere, and then it would occasionally happen that with its proper speed it would cross out into space beyond the region by which its movements would be interfered with by the collisions between other atmospheric molecules. If the attraction of the earth were sufficient to recall it, then, of course, it would duly fall back, and in the case of the more sluggishly moving atmospheric gases the velocity seems always small enough to permit the recall to be made. But it happens in the case of hydrogen that the velocity with which its molecules are occasionally animated rises beyond the speed which could be controlled by terrestrial gravity. The consequence is that every now and then a molecule of hydrogen would succeed in bolting away from the earth altogether and escaping into open space. Thus it appears that every molecule of free hydrogen which happened to be present in an atmosphere like ours would have an unstable connection with the earth, for wherever in the vicissitudes of things it happened to reach the very uppermost strata it would be liable to escape altogether. In the course of uncounted ages it would thus come to pass that the particles of hydrogen would all effect their departure, and thus the fact that there is at present no free hydrogen in the air over our heads may be accounted for.

If the mass of the earth were very much larger than it is, then the velocities with which the molecules of hydrogen went their way would never be sufficiently high to enable them to quit the earth altogether, and consequently we might in such a case expect to find our atmosphere largely charged with hydrogen. Considering the vast abundance of hydrogen in the universe, it seems highly probable that its absence from our air is simply due to the circumstances we have mentioned. In the case of a globe so mighty as the sun, the attraction which it exercises, even at the uppermost layers of its atmosphere is so intense that the molecules of hydrogen never attain pace enough to enable them to escape. Their velocity would have to be much greater than it ever can be if they could dart away from the sun as they have done from the earth. It is not, therefore, surprising to find hydrogen in the solar atmosphere. In a similar manner we can explain the abundance with which the atmospheres of other massive suns like Sirius or Vega seem to be charged with hydrogen. The attraction of these vast globes is sufficiently potent to retain even an atmosphere of this subtle element. * * *

The discussion we have just given will prepare us to believe that a planet with the size and mass of Mars may be expected to be encompassed with an atmosphere. Our telescopic observations completely bear this out. It is perfectly certain that there is a certain shell of gaseous material investing Mars. This is shown in various ways. We note the gradual obscuration of objects on the planet as they approach the edge of the disk, where they are necessarily viewed through a greatly increased thickness of Martian atmosphere. We also observe the clearness with which objects are exhibited at the center of the disk of Mars, and though this may be in some measure due to the absence of distortion from the effects of foreshortening, it undoubtedly arises to some extent from the fact that objects in this position are viewed through a comparatively small thickness of the atmosphere enveloping the planet. Clouds are also sometimes seen apparently floating in the upper region of Mars. This, of course, is possible only on the supposition that there must be an atmosphere which formed the vehicle by which clouds were borne along. It is, however, quite obvious that the extent of the Martian atmosphere must be quite insignificant when compared with that by which our earth is enveloped. It is a rare circumstance for any of the main topographical features, such as the outlines of its so-called continents or the coasts of its so-called seas, to be obscured by clouds to an extent which is appreciable except by very refined observations. Quite otherwise would be the appearance which our globe would present to any observer who would view it, say, from Mars or from some other external world at the same distance. The greater part of our globe would seem swathed with vast clouds, through which only occasional peeps could be had at the actual configuration of its surface. I dare say a Martian astronomer who had an observatory with sufficiently good optical appliances and who possessed sufficient patience might, in the course of time, by availing himself of every opportunity, gradually limn out a chart of the earth which would in some degree represent that with which we are familiar in our atlases. It would, however, be a very tedious matter, owing to the interruptions to the survey caused by the obscurities in our atmosphere. The distant astronomer would never be able to comprehend the whole of our earth's features in a bird's-eye glance, as we are able to do with those features on that hemisphere of Mars which happens to be turned toward us on a clear night.

As to what the composition of the atmosphere on Mars may be we can say but little. In so far as the sustenance of life is concerned, the main question, of course, turns on the presence or the absence of oxygen. It may be pertinent to this inquiry to remark here that a globe surrounded by air may at one epoch of its career have free oxygen as an ingredient in its atmosphere, while at other epochs free oxygen may be absent. This may arise from another cause besides the possible loss of the gas by diffusion into space from small globes in the manner already explained. Indeed, it seems quite probable that the oxygen in our own air is not destined forever to remain there. It passes through various vicissitudes by being absorbed by animals and then restored again in a free state under the influence of vegetation. But there is an appetite for oxygen among the inorganic materials of our globe which seems capable of using up all the oxygen on the globe and still remain unsatisfied. We have excellent grounds for believing that there is in the interior of the earth a quantity of metallic iron quite sufficient to unite with all the free oxygen of the air, so as to form oxide. In view of the eagerness with which oxygen and iron unite and the permanence of the compound which they form, it is impossible for us to regard the presence of oxygen in the air as representing a stable condition of things. It follows that, even though there may be no free oxygen in the atmosphere of Mars, it is by no means certain that this element has always been absent. It is, however, not at all beyond the reach of scientific resources to determine what the actual composition and extent of the atmosphere of Mars may be, though it can hardly be said that as yet we are in full possession of the truth.

An almost equally important question is as to the telescopic evidence of the presence of water on Mars. Here again we have to be reminded of the fact that even at present, when the planet is relatively so near us, it is still actually a very long way off. It would be impossible for us to say with certainty that an extent which by its color and general appearance looked like an ocean of water was really water, or was even a fluid at all. It is so easy to exaggerate the capabilities of our great telescopes that it may be well to recount what is the very utmost that could be expected from even our greatest instrument when applied to the study of Mars. Let us consider, for example, the capabilities of the Lick telescope in aiding such an inquiry as that before us. This instrument, both from its position and its optical excellence, offers a better view of Mars at the present time than can be obtained elsewhere. But the utmost that this telescope could perform in the way of rendering remote objects visible is to reduce the apparent distance of the object to about one-thousandth part of its actual amount. Some, indeed, might consider that even the Lick instrument would not be capable of giving so great an accession to our powers as this statement expresses. However, I am willing to leave the figure at this amount, only remembering that if I estimated the powers of the telescope less highly than these facts convey, the arguments on which I am entering would be correspondingly strengthened.

As we have already said, Mars is at present at a distance of 35,000,000 miles, and if we look at it through a telescope of such a power as we have described, the apparent distance is reduced to one-thousandth part. In other words, all that the best telescope can possibly do is to exhibit the planet to us as it would be seen by the unaided eye if it were brought into a distance of 35,000 miles. This will demonstrate that even our greatest telescopes can not be expected to enable us to answer the questions that are so often asked about our neighboring globe. What could we learn of Europe if we have only a bird's-eye view of it from a height of 35,000 miles; that is to say, from a height which was a dozen times as far as from the shores of Europe to America? The broad outlines of the coast might of course be seen by the contrast of the color of a continent and the color of the ocean. Possibly a great mountain mass like the Alps would be sufficiently noticeable to permit some conjecture as to its character to be formed. But it is obvious that it would be hopeless to expect to see details. The smallest object that would be discernible on Mars must be as large as London. It would not be possible to see a point so small as would either Liverpool or Manchester be if they were on that point. There is, no doubt, a remarkable contrast between the dark colors of certain parts of Mars and the ruddy colors of other parts. It would, however, be going rather far to assert that the former must be oceans of water and the latter continents of land. This may indeed be the case, and most astronomers, I believe, think that it is the case, but it certainly has not yet been proved to be so.

Undoubtedly the most striking piece of evidence that can be adduced in favor of the supposition that there is water on Mars is derived from the "snowy" poles on the planet. The appearance of the poles of Mars with their white caps is one of the most curious features of the solar system. The resemblance to the structure of our own polar regions is extremely instructive. It is evident that there must be some white material which from time to time gathers in mighty volume round the north and south poles of the planet.

It is also to be noticed that this accumulation is not permanent. The amount of it waxes and wanes in correspondence with the variations of the seasons on Mars. It increases during Mars's winter, and it declines again during Mars's summer. In this respect the white regions, whatever they may be composed of, present a noteworthy contrast to the majority of the other features on the planet. The latter offer no periodic changes to our notice; they are evidently comparatively permanent marks, not to any appreciable extent subject to seasonal variations. When we reflect that this white material is something which grows and then disappears according to a regular period, it is impossible to resist the supposition that it must be snow, or possibly the congealed form of some liquid other than water, which during Mars's summer is restored to a fluid state. There can hardly be a doubt that if we were ever able to take a bird's-eye view of our own earth its poles would exhibit white masses like those which are exhibited by Mars, and the periodic fluctuations at different seasons would produce changes just like those which are actually seen on Mars. It seems only reasonable to infer that we have in Mars a repetition of the terrestrial phenomenon of arctic regions on a somewhat reduced scale.

Among the features presented by Mars there are others in addition to the polar caps which seem to suggest the existence of water. It was in September, 1877, when Mars was placed in the same advantageous position for observation that it occupies at present, that a remarkable discovery was made by Professor Schiaparelli, the director of the Milan Observatory. In the clear atmosphere and the convenient latitude of the locality of his observatory he was so fortunate as to observe marks not readily discernible under the less advantageous conditions in which our observatories are placed. Up to his time it was no doubt well known that the surface of Mars could be mapped out into districts marked with more or less distinctness—so much so that charts of the planet had been carefully drawn and names had been assigned to the various regions which could be indicated with sufficient certainty. But at the memorable opposition to which we have referred the distinguished Italian astronomer discovered that the tracts generally described as "continents" on Mars were traversed by long, dark "canals," as he called them. They must have been each at least 60 miles wide, and in some cases they were thousands of miles in length. Notwithstanding the dimensions to which these figures correspond, the detection of the Martian canals indicates one of the utmost refinements of astronomical observation. The fact that they are so difficult to see may be taken as an illustration of what I have already said as to the hopelessness of discerning any object on this planet unless it be of colossal dimensions.

It is impossible to doubt that considerable changes must be in progress on the surface of Mars. It is true that, viewed from the distance at which we are placed, the extent of the changes, though intrinsically vast, seem relatively insignificant. There is, however, too much testimony as to the changes to allow of hesitation.

Speculations have naturally been made as to the explanation of these wonderful canals. It has been suggested that they may indeed be rivers; but it hardly seems likely that the drainage of continents on so small a globe as Mars would require so elaborate a system of rivers, each 60 miles wide and thousands of miles in length. There is, however, a more fatal objection to the river theory in the fact that the marks we are trying to interpret sometimes cross a Martian continent from ocean to ocean, while on other occasions they seem to intersect each other. Such phenomena are of course well-nigh impossible if these so-called canals were in any respect analogous to the rivers which we know on our own globe. It can, however, hardly be doubted that if we assume the dark regions to be oceans the canals do really represent some extension of the waters of these oceans into the continental masses. Other facts which are known about the planet suggest that what seem to be vast inundations of its continents must occasionally take place. Nor is it surprising that such vicissitudes should occur on a globe circumstanced like Mars. Here, again, it is well to remember the small size of the planet, from which we may infer that it has progressed through its physical evolution at a rate more rapid than would be possible with a larger globe, like the earth. The sea is constantly wearing down the land, but, by upheavals arising from the intensely heated condition of the interior of our globe, the land is still able to maintain itself above the water. It can, however, hardly be doubted that if our earth had so far cooled that the upheavals had either ceased or were greatly reduced the water would greatly encroach on the land. On a small globe like Mars the cooling of the interior has so far advanced that in all probability the internal heat is no longer an effective agent for indirectly resisting the advance of the water, and consequently the observed submergence is quite to be expected.

That there may be types of life of some kind or other on Mars is, I should think, very likely. Two of the elements, carbon and hydrogen, which are most intimately associated with the phenomena of life here, appear to be among the most widely distributed elements throughout the universe, and their presence on Mars is in the highest degree probable. But what form the progress of evolution may have taken on such a globe as Mars it seems totally impossible to conjecture. It has been sometimes thought that the ruddy color of the planet may be due to vegetation of some peculiar hue, and there is certainly no impossibility in the conception that vast forests of some such trees as copper beeches might impart to continental masses hues not unlike those which come from Mars. Speculations have also been made as to the possibility of there being intelligent inhabitants on this planet, and I do not see how anyone can deny the possibility, at all events, of such a notion. I would suggest, however, that as our earth has only been tenanted by intelligent beings for an extremely brief part of its entire history—say, for example, for about one-thousandth part of the entire number of years during which our globe has had an independent existence—so we may fairly conjecture that the occupancy of any other world by intelligent beings might be only a very minute fraction in the span of the planet's history. It would therefore be highly improbable, to say the least of it, that in two worlds so profoundly different in many respects as are this earth and Mars the periods of occupancy by intelligent beings should happen to be contemporaneous. I should therefore judge that, though there may once have been or though there may yet be intelligent life on Mars, the laws of probability would seem against the supposition that there is such life there at this moment.

We have also heard surmises as to the possibility of the communication of interplanetary signals between the earth and Mars, but the suggestion is a preposterous one. Seeing that a canal 60 miles wide and 1,000 miles long is an object only to be discerned on exceptional occasions and under most favorable circumstances, what possibility would there be that, even if there were inhabitants on Mars who desired to signal this earth, they could ever succeed in doing so? We are accustomed to see ships signaling by flags, but what would have to be the size of the flags by which the earth could signal to Mars or Mars signal to the earth? To be effective for such purpose each of the flags should be at least as big as Ireland. It is true, no doubt, that small planets would be fitted for the residence of large beings, and large planets would be proper for small beings. The Lilliputians might be sought for on a globe like Jupiter, and the Brobdingnagians on a globe like Mars, and not vice versa, as might be hastily supposed. But no Brobdingnagian's arms would be mighty enough to wave the flag on Mars which we should be able to see here. No building that we could raise, even were it a hundred times more massive than the Great Pyramid, would be discernible by the Martian astronomer, even had he the keenest eyes and the most potent telescopes of which our experience has given us any conception.

II. The Canals of Mars.[1]

By Miss M. A. Orr.

The physical condition of Mars is a problem over which discussion still rages with unabated vigor. While Mr. Lowell sees in the Martian "canals" a vast system of artificial irrigation, and M. du Ligondès geological fissures, through which rise to the frozen surface vivifying vapors from a still heated interior, M. Antoniadi ascribes their doubling to a defect in focusing, and others disbelieve in even their single existence. But the enigmatical lines have appeared to so many, and in the main with such consistent similarity, that the ranks of these unbelievers grow thin. Between rejecting the canals altogether, however, and accepting them as actual physical entities there are other possible alternatives. Mr. Walter Maunder, in an article in Knowledge for November, 1894, and more recently Signor Cerulli, in recounting his observations of Mars in the opposition of 1896–97, at his private observatory of Collurania (Teramo), showed how the mathematical

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[1] From Knowledge, February 1, 1901. [See article on Canals of Mars in Smithsonian Report for 1894.]

lines and spots we find in the faint markings of Mars might be merely the easiest form in which, with our present optical means, we could be cognizant of its real features. This latter treatise elicited replies from Schiaparelli and Flammarion, but their arguments in favor of the physical existence of the markings as such, and of actual changes taking place in them, are not altogether conclusive. Signor Cerulli's observations during the last opposition have confirmed him in the belief that the markings are optical, and his new report[1] is substantially a full exposition of his theory. These observations extended from August, 1898, to March, 1899, and were made with a 15½-inch Cooke equatorial, with powers of 400 and 500, always without stops or colored screens, the object being not to get sharp definition of any special feature, but as complete a picture as might be of all the phenomena. The author shows what is the explanation, on his theory, of the features seen and their apparent variations, and brings forward ingenious and novel arguments to prove his case.

It must be remembered that in a bird's-eye view of a world some 40,000,000 miles away all we can take note of are contrasts in tone or color, while the real contour of objects is masked or invisible. Small or faintly shaded objects, invisible singly, will produce an effect, if close together, of one large mass, and from our inability to see the irregularity of their grouping will appear as round spots or long streaks. But conditions of seeing vary enormously on Mars, according to its distance and position and the changing illumination of its disk, not to speak of variations in ourselves, our atmosphere, and our instruments. The contrasts, therefore, will vary, more detail will sometimes be seen in the patches and streaks, fainter markings at their edges will appear and disappear, altering their outline and extent. The hazy aspect of Schiaparelli's canals may thus be a nearer approximation to reality than the sharply defined, and the doubling may be due to disappearance of faint shadings between more easily grasped boundaries. That the canals were discovered after the opposition of 1877, being only suspected during the most favorable period, that they are sharpest with colored screens and comparatively small apertures, while in the great Lick and Washington telescopes they have been seen either as few diffused markings or not at all, suggest that the fine lines are simply a mode under which faint markings may present themselves to imperfect vision. There is undoubtedly truth in the apparent paradox that greater distinctness comes with poorer vision, for in the best moments the eye dimly perceives, even where it can not grasp, divisions in simple masses, curves, and blurring in narrow lines, indeterminate shadows in clear spaces.

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[1] Nuove osservazioni di Marte: Saggio di una interpretazione ottica delle sensazioni areoscopiche. By V. Cerulli. Collurania, 1900.

Whether the optical theory accounts for all the variations, including those of the polar caps, the future must decide. Most interesting is Cerulli's appeal to the past history of areography, referring to Flammarion's valuable collection of drawings, all carefully copied from originals, in his Planète Mars. Here we may see now in the first rude telescopes impressions of Martian markings were summed up in one large round spot, or one wide band, which latter was by Cassini and some others seen double. By degrees the easiest features of the Southern Hemisphere were distinguished, but appeared so variable that an atmospheric origin was ascribed to them. It is particularly instructive to compare Knott's drawing of November 3, 1862, with Lord Rosse's of three days later. Knott's telescope was of 7⅓-inch aperture, and the features which in the 6-foot Rosse reflector appeared as large dark patches on a fainter background he portrays as narrow lines on white—canals on a large scale. Again, in two excellent drawings by Kaiser, a broad band where we now recognize Praxodes, seen at the opposition of 1862, becomes, six weeks later, when seeing was more difficult, two narrow bands with faint shadings between. Other examples of gemination in lines and in spots, contractions and enlargements, etc., may be traced, and through all the series there is a remarkable, but in no wise astonishing, variety of representation. One has but to consider the fugitive faintness of the objects, the imperfections of the instruments, and the personality of the observers, which affects not only their vision but their mode of portrayal. On this last point, which comes out very clearly on an examination of the illustrations in La Planète Mars, Signor Cerulli has not perhaps laid enough stress, nor on the influence of unconscious imitation.

Mr. Green, the artist astronomer, used to insist on the importance of the trained hand as well as the trained eye in order to obtain true pictures of planetary detail.

Is the history of discovery with regard to the large markings in Mars's southern hemisphere repeating itself now with the more delicate shadings in the northern? And with better optical means would they also lose their misleading appearance of mathematical regularity and their instability?

The artificial origin of the Martian "canals" can hardly be maintained now that they have been seen to traverse the polar caps and to appear in Venus, Mercury, and two of the Jovian satellites. On the optical hypothesis, on the other hand, this is precisely what we might expect. It is perhaps going too far to suggest that the bands of Jupiter and their varying appearances are strictly analogous to canals, since their atmospheric origin is rendered probable by other considerations, notably by the planet's low density; yet there is certainly a startling resemblance between some early drawings of Mars and recent diagrams of Jupiter. Schröter's Mars, for instance, on page 77, fig. 48, of "La Planète Mars" (1892 edition), tempts one to quote Dante:

> Such would Jove become, if he and Mars
> Were birds, and changed their plumage.

We are indebted to M. Flammarion for another line of evidence. He had the happy idea of collecting naked-eye views of the moon by different observers, and in response to his appeal an interesting series appeared in the Bulletin de la Société Astronomique de France from January to June of last year. The disk of the moon to the unaided eye is about the same size as that of Mars in an average telescope, but the conditions are not quite the same, as naked-eye vision does not admit of straining and misfocusing to the same extent as telescopic. Nevertheless, the study of these drawings is, as M. Flammarion remarks, a lesson on the value to be attached to observations at the limit of visibility, and no one would have believed that the same thing could have been represented in so many different ways. The reader may judge for himself by personal examination whether these drawings support Cerulli's theory of the canals. He will not fail to observe a tendency to draw the Seas of Serenity, Tranquillity, Plenty, and Nectar, as two lines more or less parallel, while the Ocean of Tempests is sometimes a narrow, curved line, its eastern border only being seen in contrast with the brilliant limb. Tycho in one instance appears as a very large bright square.

Whether the optical theory be correct or no, probably no one will deny the wisdom of Signor Cerulli's advice to regard all Martian maps as temporary guides, sure to be modified by further investigation. We may add, however, that to refrain altogether from speculative hypotheses would be as unscientific as uninteresting; the sensational theories about Mars have been a stimulus to much excellent work; but the scientist remembers that they are only theories and is prepared to see them dispelled by fuller light.

III. The Message from Mars.[1]

Writing from Lowell Observatory, Flagstaff, Ariz., Prof. A. E. Douglass says in the Boston Transcript: The phenomenon on Mars which has given rise to the report of a message from that planet on December 7 of last year was really only a cloud on that planet lighted up by the setting sun. It was a true message, giving us knowledge of Martian climate, but not a message from any intelligent inhabitants. A great number of clouds of this kind have been seen in previous years, but none, I believe, for the last four, and therefore this one, coming as it did in one particular part of the planet, was a matter of great interest, and I telegraphed information about it to the East,

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[1] From Boston Transcript, February 2, 1901.

where it was distributed to all astronomers and to many others interested.

Astronomers almost never see clouds on the sunlit portions of the planet. If they exist as thin cirrus clouds, we should perhaps be unable to see them. Heavy clouds, if they covered a large enough area of the planet, would be visible. They would have to cover perhaps a million square miles before they could be recognized with certainty. But on this earth they cover far more area than that, and therefore, as we do not see them on Mars at all, we conclude that the planet is extremely dry. As a matter of fact, it has no oceans and no surfaces that are positively identified as permanent water surfaces. Some observers even doubt that the planet is warm enough to permit the existence of water. The only two indications of water, however, are in the polar caps of snow and the clouds, such as this one, which becomes visible to us as the sun sets on the region above which they float. These clouds stand above such regions like the peaks of high mountains, and receive the last rays of the setting sun, when all beneath is dark. They therefore appear to us as bright spots against a dark background or as bright points extending from the sunlit portion of the planet out into the region of night.

The first observation of a phenomenon of this kind was made at the Lick Observatory in 1890. A few were seen in 1892 at a number of observatories. Over 350 were observed and studied at this observatory in 1894, and many were seen in 1896. The result of the study of several hundred of them is given in Vol. I of the Annals of the Lowell Observatory. By that research it became evident that many of them were formed at sunset. In character they were probably like our dense cumulus clouds. Their average elevation was much greater than our cumulus clouds, being several miles on an average, and one was seen at least as high as 15 miles above the surface, that of November 25, 1894. In that case the cloud was seen near the sunrise terminator, as it is called—that is, the north and south line on the planet at which the sun was rising. If we were searching for signals, the cloud of November 25, 1894, would be a very much more striking case than anything seen before or since. On the night of November 25 this cloud was seen as a white spot against the dark background of the unillumined surface beneath. It was 100 miles across and at least 15 miles above the surface. It remained in that point over half an hour, then suddenly disappeared. On the following night it was only 8 miles high. Instead of remaining constantly as a bright spot, it appeared and disappeared. The first appearance lasted sixteen minutes; after four minutes it disappeared; it came again for only a moment, and after six minutes more it again appeared for two and one-half minutes. Then followed an absence of three minutes, presence for two minutes, absence for three minutes, presence one minute, absence eight minutes, and a final brief appearance forty-six minutes after the first sight of it.

If some genius can prove that these were a series of signals from Mars, it would be a matter of the greatest importance. My own belief is that it was a message from Mars, not from inhabitants of the surface, but from the clouds which inhabit its atmosphere. They were giving us an illustration of the effect on them of sunlight and showing us how they form and disappear with its absence and presence.

The cloud which was observed on December 7 and 8 gave us also a scientific message of great importance. It was seen on those two successive mornings and lasted for an hour each time. It was less on the second morning, as if the moisture had been dissipated, or had been used in some way so that it could not condense into visible clouds. It formed above the deserts on the north side of a large, dark marking on the planet, Icarium Mare, which is supposed to be vegetation. This is significant in two ways. First, it corroborates our idea that the dark markings are vegetation by showing, as we should expect, that the regions of vegetation have more moisture in them than the surrounding regions, which are desert. Second, it appeared on the north side of the dark marking, showing that there must have been a motion of the air from the south. That is, at this point on the equator, in a season which corresponds to our April 23, the wind was from the south. At that time the sun was about 13° north of the equator, and the point beneath most heated by the sun was therefore north also, and the wind was blowing toward that point. This is exactly what we find on the earth in the case of the trade winds, which blow toward the heat equator. And so we have received the most interesting information that in these zones, at least, the winds on Mars and on the earth blow in the same direction.

Knowing, then, that such similarity exists, scientists can advance with confidence from a knowledge of our own weather conditions to those on Mars. They can have the satisfaction of knowing that their theories are not pure speculation. This, then, is the important message which we have received from Mars.

IV. Messages from Mars.[1]

We feel that some apology is needed for the appearance in these pages of a note with this sensational heading; but there have been so many paragraphs lately in the daily press under the title that, on the sole ground that this is a chronicle of astronomical and quasi-astronomical events, we think the subject should be mentioned. First, a telegram came from America saying that Mr. Douglass, at Lowell Observatory, Ariz., had seen a projection on the northern edge of

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[1] Extract from The Observatory, London, February, 1901, p. 102.

Icarium Mare, which remained visible for more than an hour. Some one interpreted this by the well-worn surmise that the Martian inhabitants were signaling to us. Sir Robert Ball tried to convince the public of the fallacy of this in one of his lectures at the Royal Institution, and M. Flammarion, with the same end in view, explained to an interviewer that this appearance was probably a sunset effect on our neighbor. Next, Mr. Nikola Tesla, having a wireless-telegraphy apparatus on a mountain in America, said that he had noticed effects on his receiver for which he could not account, and therefore he concluded that they must have been caused by the inhabitants of Mars. The message, according to Mr. Tesla, was not particularly lucid, being, as he said, merely "one, two, three;" but he did not hesitate to explain that it is quite within the bounds of possibility to establish electrical communication with our neighbor. These utterances, which have been cabled at length to the English papers, have furnished texts for many jocose paragraphs and small poems; the interviewers have been busy. * * * M. Loewy very naturally asked his interviewer, "Why Mars? How did Mr. Tesla know that it was not Venus or Mercury who was signaling?"

A third matter, which comes under the heading, relates to a bequest of a Mme. Guzmann, who in 1891 left 100,000 francs to be awarded as a prize to the first person who shall be successful in communicating with another world other than the planet Mars. The Academy hesitated to accept the bequest, but has at last done so, influenced, perhaps, by the fact that the will goes on to say that each time the prize has not been awarded for a period of five years the accumulated interest shall be attributed to a work seriously helping the progress of astronomy. The Academy, in accepting the trust, remarks that the intentions of the founder will be scrupulously executed, and quotes from Montaigne: "It is a stupid presumption to condemn as false all that which may not appear likely to us. There is no greater madness in the world than to reduce everything to the measure of our capacity and competence." But why is Mars excluded? Is it to bar Mr. Tesla?

ON SOLAR CHANGES OF TEMPERATURE AND VARIATIONS IN RAINFALL IN THE REGION SURROUNDING THE INDIAN OCEAN.[1]

By Sir NORMAN LOCKYER, K. C. B., F. R. S., and W. J. S. LOCKYER, M. A. (Camb.), Ph. D. (Gött.).

The fact that the abnormal behavior of the widened lines in the spectra of sunspots since 1894 had been accompanied by irregularities in the rainfall of India suggested the study and correlation of various series of facts which might be expected to throw light upon the subject.

The conclusions already arrived at from bringing together the results of several investigations undertaken with this view may be stated as follows:

(1) It has been found from a discussion of the chemical origin of lines most widened in sunspots at maxima and minima periods that there is a considerable rise above the mean temperature of the sun around the years of sunspot maximum and a considerable fall around the years of sunspot minimum.

(2) It has been found from the actual facts of rainfall in India (during the southwest monsoon) and Mauritius, between the years 1877 and 1886, as given by Blanford and Meldrum, that the effects of these solar changes are felt in India at sunspot maximum, and in Mauritius at sunspot minimum. Of these the greater is that produced in the Mauritius at sunspot minimum. The pulse at Mauritius at sunspot minimum is also felt in India, and gives rise generally to a secondary maximum in India.

India therefore has two pulses of rainfall, one near the maximum and the other near the minimum of the sunspot period.

(3) It has been found that the dates of the beginning of these two pulses on the Indian and Mauritius rainfall are related to the sudden remarkable changes in the behavior of the widened lines.

(4) It has been found from a study of the famine commission reports that all the famines therein recorded which have devastated India during the last half century (we have not yet carried the investigation further back) have occurred in the intervals between these two pulses.

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[1] Reprinted (abridged) from Nature, November 29 and December 6, 1900.

(5) It has been found from the investigation of the changes in (1) the widened lines, (2) the rainfall of India, and (3) of the Mauritius during and after the last maximum in 1893 that important variations from those exhibited during and after the last maximum of 1883 occurred in all three.

It may be stated at the same time that the minimum of 1888–89 resembled the preceding minimum of 1878–79.

(6) It has been found from an investigation of the Nile curves between the years 1849 and 1878 that all the lowest Niles recorded have occurred between the same intervals.

(7) The relation of the intervals in question to the droughts of Australia and of Cape Colony and to the variations in the rainfall of extratropical regions generally has not yet been investigated. We have found, however, a general agreement between the intervals and the rainfall of Scotland (Buchan), and have traced both pulses in the rainfalls of Córdoba (Davis) and the Cape of Good Hope.

(8) We have had the opportunity of showing these results to the meteorological reporter to the government of India and director-general of Indian observatories, John Eliot, esq., C. I. E., F. R. S., who is now in England, and he allows us to state his opinion that they accord closely with all the known facts of the large abnormal features of the temperature, pressure, and rainfall in India during the last twenty-five years, and hence that the inductions already arrived at will be of great service in forecasting future droughts in India.

SOLAR PHYSICS OBSERVATORY, *October 26.*

ADDENDUM.

Since Meldrum and one of us called attention, in 1872, to a possible connection between sunspots and rainfall, there has been a large literature upon the subject which it is not necessary for us to analyze; it may be simply stated that, in spite of the cogent evidence advanced since, chiefly by Meldrum, and in later years by Mr. Hutchins,[1] it is not yet generally accepted that a case for the connection has been made out.

What has been looked for has been a change at maximum sunspots only, the idea being that there might be an effective change of solar temperature, either in excess or defect, at such times, and that there would be a gradual and continuous variation from maximum to maximum.

At the same time it is possible that the pressure connection, first advanced by Chambers, is now accepted by meteorologists as a result of the recent work of Eliot.

The coincidence, during the last few years, of an abnormal state of the sun with abnormal rain in India, accompanied by the worst famine

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[1] "Cycles of Drought and Good Seasons in South Africa, 1889."

experienced during the century, suggested to us the desirability of reconsidering the question, especially as we have now some new factors at our disposal. These have been revealed by the study, now extending over twenty years, of the widened lines in sunspots, which suggested the view that two effects ought to be expected in a sunspot cycle instead of one.

THE WIDENED LINES.

It will be gathered from previous communications to the Royal Society[1] that, on throwing the image of a sunspot on the slit of a spectroscope, it is found that the spectrum of a spot so examined indicates that the blackness of the spot is due not only to general, but to selective absorption,[2] and that the lines widened by the selective absorption vary from time to time.

Since the year 1879 the selective absorption in spots has been observed for every spot that was large enough to be spectroscopically examined, the method adopted being as follows:

The regions of the spectrum investigated lie between F—*b* and *b*—D, and an observation consists in observing the six most widened lines in each of these regions. These lines are then identified on the best solar spectrum maps available and their wave lengths determined.

An examination of many years' records of these widened lines has shown that at some periods they are easily traceable to known elements, while at others their origins have not been discovered, so the latter have been classed as "unknown" lines. If we compare these two periods with the sun-spot curve as constructed from the measurements of the mean spotted area for each year, it is found that when the spotted area is greatest the widened lines belong to the "unknown" class, while when the spotted area is least they belong to the "known" class.

The majority of the lines traced to some terrestrial origin belong to iron, but the lines of other elements, such as titanium, nickel, vanadium, scandium, manganese, chromium, cobalt, etc., are also represented in a less degree.

It is quite likely that some of the "unknown" lines are higher temperature (enhanced) lines of known chemical elements.

In our laboratories we have means of differentiating between three stages of temperature, namely, the temperature of the flame, the electric arc, and the electric spark of the highest tension. At the lowest temperature, that of the flame, we get a certain set of lines; a new set is seen as the temperature of the electric arc is reached. At the temperature of the high-tension spark we again have many new

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[1] Proc. Roy. Soc., vol. xl, p. 347, 1886; vol. xlii, p. 37, 1887; vol. xlvi, p. 385, 1889; vol. lvii, p. 199, 1894.

[2] P. R. S., Lockyer, 1866, October 11.

lines, called enhanced lines, added, while many of the arc lines wane in intensity.

It is found that at sun-spot minimum, when the "known" lines are most numerous, the lines are almost invariably those seen most prominent in the arc. Passing from the sun-spot minimum toward the maximum the "unknown" lines gradually obtain the predominance. As said before, they may be possibly "enhanced lines;" that is, lines indicating the action of a much higher temperature on known substances.

Unfortunately the records of enhanced lines at South Kensington, having been obtained from photographs, are chiefly confined to a region of the spectrum not covered by the visual observations of widened lines in sun-spot spectra.

We can only point to the evidence acquired in the case of one metal—iron—for which photographs of the enhanced lines in the green and yellow parts of the spectrum have been obtained.

This evidence quite justifies the above suggestion, for the enhanced lines of iron can be seen revealing themselves as the number of unknown lines increases.

We are, therefore, quite justified in assuming a very great increase of temperature at the sun-spot maximum when the "unknown" lines appear alone.

The curves of the "known" and "unknown" lines have been obtained by determining for each quarter of a year the percentage number of known and unknown lines and plotting these percentages as ordinates and the time elements as abscissæ. Instead of using the mean curves for all the known elements involved, that for iron is employed, as it is a good representative of "known" elements, and has been best studied. When such curves have been drawn, they cross each other at points where the percentage of unknown lines is increasing, and that of the iron or known lines are diminishing, or vice versa.

We seem, therefore, to be brought into the presence of three well-marked stages of solar temperature.

When the curves of known and unknown lines cross each other—that is, when the number of known and unknown lines is about equal—we must assume a mean condition of solar temperature. When the unknown lines reach their maximum, we have indicated to us a + pulse or condition of temperature. When the known lines reach their maximum, we have a — pulse or condition of temperature.

The earliest discussion showed that, generally speaking, the unknown-lines curve varied directly and the iron-lines curve varied inversely with the spot-area curve. The curves now obtained for the whole period of twenty years not only entirely indorse this conclusion, but enable more minute comparisons to be drawn.

The "widened line" curves are quite different from those furnished by the sun spots. Ascents and descents are both equally sharp, changes are sudden, and the curves are relatively flat at top and bottom. The crossings are sharply marked.

During the period since 1879 three such crossings have occurred, indicating the presence of mean solar temperature conditions, in the years 1881, 1886–87,[1] and 1892. It was expected that another crossing with the known lines on the rise would have occurred in 1897, indicating thereby the arrival of another mean condition of solar temperature, but as yet no such crossing has taken place. * * *

It becomes, therefore, of the first importance to correlate the times of mean solar temperature, and of the + and − heat pulses, with the solar weather cycle, in order to arrive at the temperature history of the sun during the period which now concerns us. * * *

CONNECTION OF THE SPOTS WITH PROMINENCES.

In 1869, when a sun-spot maximum was approaching, the prominences were classified by one of us into eruptive and nebulous; the former showing many metallic lines, the latter the hydrogen and helium lines chiefly. * * *

The eruptive prominences, unlike the nebulous ones, were not observed in all heliographic latitudes; but, according to the extended observations of Tacchini and Ricco, had their maxima in the same latitude as the spots. * * * This is corroborated by what Professor Respighi many years ago stated: "In correspondence with the maximum of spots, not only does the number of the large protuberances increase, but more than this—their distribution over the solar surface is radically modified." * * *

In photographs near sun-spot maximum the concentration of the prominences in zones parallel to the Equator is perfectly obvious at a glance. Eruptive or metallic prominences are thus seen to cover a much larger area than the spots, so that we have the maximum of solar activity indicated, not only by the increased absorption phenomena indicated by the greater number of the spots, but by the much greater radiation phenomena of the metallic prominences; and there seems little doubt that in the future the measure of the change in the amount of solar energy will be determined by the amount and locus of the prominence area.

Spots are, therefore, indications of excess of heat, and not of its defect, as was suggested when the term "screen" was used for them. We know now that the spots at maximum are really full of highly

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[1] According to the observations the mean was reached in December, 1886, or January, 1887.

heated vapors produced by the prominences, which are most numerous when the solar atmosphere is most disturbed. * * *

The Indian meteorologists have abundantly proved that the increased radiation from the sun on the upper air currents at maximum is accompanied by a lower temperature in the lower strata, and that with this disturbance of the normal temperature we must expect pressure changes. Chambers was the first to show that large spotted area was accompanied by low pressures over the land surface of India. (Abnormal Variations, p. 1.) * * *

INDIAN RAINFALL. SOUTHWEST MONSOON, 1877–1886.

It will be clear from what has been stated that our object in studying rainfall was to endeavor to ascertain if the + and — temperature pulses in the sun were echoed by + and — pulses of rainfall. The Indian rainfall was taken first, not only because in the Tropics we may expect the phenomena to be the simplest, but because the regularity of the Indian rains had broken down precisely when the widened line observations showed a most remarkable departure from the normal. * * *

The first investigation undertaken was the study of the rainfall tables published by the meteorological department of the government of India. These were brought together by Blandford down to the year 1886.[1] As the widened line observations were not begun at Kensington till 1879, the discussion was limited in the first instance to the period 1877–1886, inclusive, embracing the following changes in solar temperature, occurring, as will be seen, between two conditions of mean solar temperature:

Mean.	— pulse.	Mean.	+ pulse.	Mean.
1876	1877–1880	1881	1882–1886	1886–1887

* * * It soon became evident that in many parts of India the + and — conditions of solar temperature were accompanied by + and — pulses producing pressure changes and heavy rains in the Indian Ocean and the surrounding land. These occurred generally in the first year following the mean condition, that is, in 1877–78 and 1882–83, dates approximating to, but followed by, the minimum and maximum periods of sun spots.

Meldrum, as far back as 1881,[2] referred to "the extreme oscillations of weather changes in different places, at the turning points of the curves representing the increase and decrease of solar activity."

It was especially in regions such as Malabar and the Konkan, when the monsoon strikes the west coast of India, that the sharpness and individuality of these pulses was the most obvious. * * *

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[1] Indian Meteorological Memoirs, Vol. III.

[2] On the Relations of Weather to Mortality, and on the Climatic Effect of Forests.

THE RAINFALL OF "WHOLE INDIA."

The next step was to work on a longer base, and for this purpose Eliot's whole India table of rainfall, 1875–1896 (Nature, vol. lvi. p. 110), embracing both the southwest and northeast monsoons, being at our disposal, was studied.

It was anticipated that such a table, built up of means observed over such a large area and during both monsoons, would more or less conceal the meaning of the separate pulses observed in separate localities; this we found to be the case. * * *

The pulses in the period stand as follows:

	Percentage variation.	Heat pulse.		
Min. 1878	+15	—		Years after rise of iron lines.
Max. 1882	+ 6	+	Years after rise of	
Min. 1889	+ 6	—		
Max. 1893	+22	+	unknown lines.	

The variations in the intensities of the pulses of rain at the successive maxima and minima are very remarkable and suggest the working of a higher law, of which we have other evidence. But, putting this aside for the present, it should be pointed out that even normally we should not expect the same values for the rainfalls in 1882 and 1893, because the amount of spotted area was so different, 1,160 millionths of the solar surface being covered with spots in 1883, and 1,430 in 1893.

The very considerable variation in the quantity of snowfall on the Himalayas has often been pointed out by the Indian meteorologists. * * *

The Himalayan snowfall, beyond all question, follows the same law as the rain, the values occurring at the + and — pulses, as under, being among the highest:[1]

		Inches.
—	67–8	134
+	71–2	110
—	77–8	207
+	82–3	81

From these tables it follows that both in rainfall and snow the quantity is increased in the years of the rise both of the unknown and iron lines. * * *

THE MAURITIUS RAINFALL.

* * * With regard to the general rainfall of Mauritius throughout the year, it may be stated that on the average the most rainy months are from December to April, both months inclusive.

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[1] Indian Meteorological Memoirs, Vol. III, p. 235.

The months of November and May are those in which the daily rainfall is increasing and diminishing, respectively. Sometimes in July or August there is a slight tendency for a small increase.

THE MAURITIUS RAINFALL CURVES FOR THE PERIOD 1877–1886.

In plotting the Mauritius rainfall curve for the period 1877–1886, it was observed that the curve is of a fairly regular nature, showing alternately an excess and deficiency of rainfall. * * *

Comparing the times of occurrence of the two pulses of rainfall at Mauritius with the times of the crossings of the known and unknown lines, it is found that the Mauritius maximum rainfall of 1877 occurs about a year after the rise of the known lines in 1876. The next Mauritius pulse of rainfall in 1882 follows the succeeding crossing, when the unknown lines are going up, also about a year later. * * *

The delay of about a year in the effect of the Mauritius pulse being felt in Ceylon and India is exactly what would be expected if the rain at sun-spot minimum comes from the south, as has been surmised.

The fact that the pulses at Mauritius, Ceylon, and India in 1882 occur simultaneously is very strong evidence in favor of an origin in the equatorial region itself for the Indian rain at sun-spot maximum. The pulse at maximum in the Indian southwest monsoon may depend to a large extent upon the action of the excess of solar heat on the equatorial waters to the south of India, and not on an abnormal effect on the southeast trade. * * *

RESULT OF THE COMPARISON OF RAINFALL.

It seems quite certain that we are justified in associating the 1878 pulse of rainfall during the southwest monsoon in India with the rainfall common to Mauritius, Batavia, and the Cape at that date; that in all cases the rain has been associated with some special condition connected with the southeast trade in the Indian Ocean.

The rainfall of Cordova suggests that the same trade wind in the Atlantic Ocean was similarly affected at the same time. * * *

SUBSIDIARY PULSES.

In a normal sun-spot curve we find a sharp rise, generally taking three or three and a half years, to maximum, and a slow decline to minimum, on which the remaining years of the cycle are spent.

The curve on the upward side rises generally regularly and continuously; on the downward portion the regularity of the curve is very often broken by a "hump" or sudden change of curvature. There has not yet been a complete discussion of the number and character of the prominences associated with the spots during the cycle; we have found, however, that the "hump" in the sun-spot curve in 1874 was accompanied by a remarkable increase in the number of eruptive prominences. * * *

THE INTERVALS BETWEEN THE PULSES.

There will obviously be intervals between the ending of one pulse and the beginning of the next, unless they either overlap or become continuous.

The + and — pulses, to which our attention has been chiefly directed, are limited in duration; and when they cease the quantity of rain which falls in the India area is not sufficient without water storage for the purposes of agriculture; they are followed, therefore, by droughts, and at times subsequently by famines.

Taking the period 1877–1889 we have

Rain from — pulse	77 78 79 (part)
No rain pulse	79 (part) 80 (central year) 81 (part)
Rain from + pulse	81 (part) 82 83 84 (part)
No rain pulse	84 (part) 85 } (central years) 86 } 87 (part) 87 (part)
Rain from — pulse	88 89

The duration of these + and — pulses of rainfall was determined in the first instance by the Mauritius rainfall, which shows both pulses; and later from the Malabar rainfall, which perhaps shows the effect of the southwest monsoon in its greatest purity.

All the Indian famines since 1836 (we have not gone back further) have occurred in these intervals, so far as they can be carried back on the assumption of an eleven-year cycle.

The following tables show the result for the two intervals:

The interval between the pulses, taking 1880 as the central year, on the upward curve.

1880 Madras famine.
N.W.P. famine.
1880—11=1869, N.W.P. famine (1868–69).
1869—11=1858, N.W.P. famine (1860).
1858—11=1847.
1847—11=1836, Upper India famine (1837–38). (Great famine.)

The interval between the pulses, taking 1885–86 as the central years, on the descending curve.

1885–86 {Bengal famine, Madras famine} (1884–85).
1885–86—11=1874–75, N.W.P. famine (1873–74).
Bombay famine (1875–76).
{Bombay famine, Upper India famine} (1876–77).

1874–75—11=1863–64, $\left\{\begin{array}{l}\text{Madras famine}\\ \text{Orissa famine}\end{array}\right\}$ (1865–66).
1863–64—11=1852–53, Madras famine (1854).

It is clear from the above table that if as much had been known in 1836 as we know now, the probability of famines at all the subsequent dates indicated in the above tables might have been foreseen.

The region of time from which the above results have been obtained extended from 1877 to 1886. The next table will show that if the dates, instead of being carried back, are carried forward, the same principle enables us to pick up the famines which have devasted India during the period 1886–1897.

Same intervals, going forward.

1880.
+11 1891, N.W.P. famine (1890).
$\left.\begin{array}{l}\text{Madras famine}\\ \text{Bombay famine}\\ \text{Bengal famine,}\end{array}\right\}$ (1891–92).
(1885–86).
+11 1896–97, General famine.

This result has arisen, so far as we can see, from the fact that the + and — pulses included in the period 1877–1886 were normal—that is, were not great departures from the average.

NILE FLOODS.

After we had obtained the above results relating to the law followed by the Indian famines we communicated with the Egyptian authorities with a view of obtaining data for the Nile Valley.

We have since found, however, from a memorandum by Mr. Eliot,[1] that Mr. Willcocks, in a paper read at the Meteorological Congress at Chicago, remarked that "famine years in India are generally years of low flood in Egypt."

It remains only for us, therefore, to point out that the highest Niles follow the years of the + and — pulses. Thus:

1871, one year after + pulse 1870.
1876, two years after subsidiary pulse of 1874.
1879, two years after — pulse 1877.
1883–84, one and two years after + pulse 1882.
1893–94, after + pulse 1892 (India excess rainfall, 1892–93–94).

THE GREAT INDIAN FAMINE OF 1899.

When, in a sun-spot cycle, the solar temperature is more than usually increased the regularity of the above effects is liable to be broken as the advent of the — pulse is retarded.

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[1] Forecast of southwest monsoon rains of 1900.

This, as we have already pointed out, is precisely what happened after the abnormal + heat pulse of 1892, following close upon the condition of solar mean temperature.

The widened line curves, instead of crossing, according to the few precedents we have, in 1897 or 1898, have not crossed yet—that is, the condition of ordinary solar mean temperature has not even yet been reached.

We have shown that, as a matter of fact, in a normal cycle India is supplied from the southern ocean during the minimum sun-spot period and that this rain is due to some pressure effect brought about in high southern latitudes by the sun at — temperature.

As the — temperature condition was not reached in 1899, as it would have been in a normal year, the rain failed.

We may say then that the only abnormal famine recorded since 1836 occurred precisely at the time when an abnormal effect of an unprecedented maximum of solar temperature was revealed by the study of the widened lines. * * *

NOTE BY MR. LANGLEY.

We find that in the charts certain lines, whose character is to us unknown, reach their maximum at the same time that the sun spots do, while another class of lines, which are known, attain their minimum at the same time.

It may not at first be entirely clear to the general reader how our knowledge or our ignorance can appear as active factors in determining the position of lines in the sun, as they seemingly do, but the paradox is easily explained when we notice that the lines of which we are ignorant are those which are associated at such high temperatures that we can not observe them, while those which we know, are dissociated at temperatures which bring them within the range of the means in our laboratories.

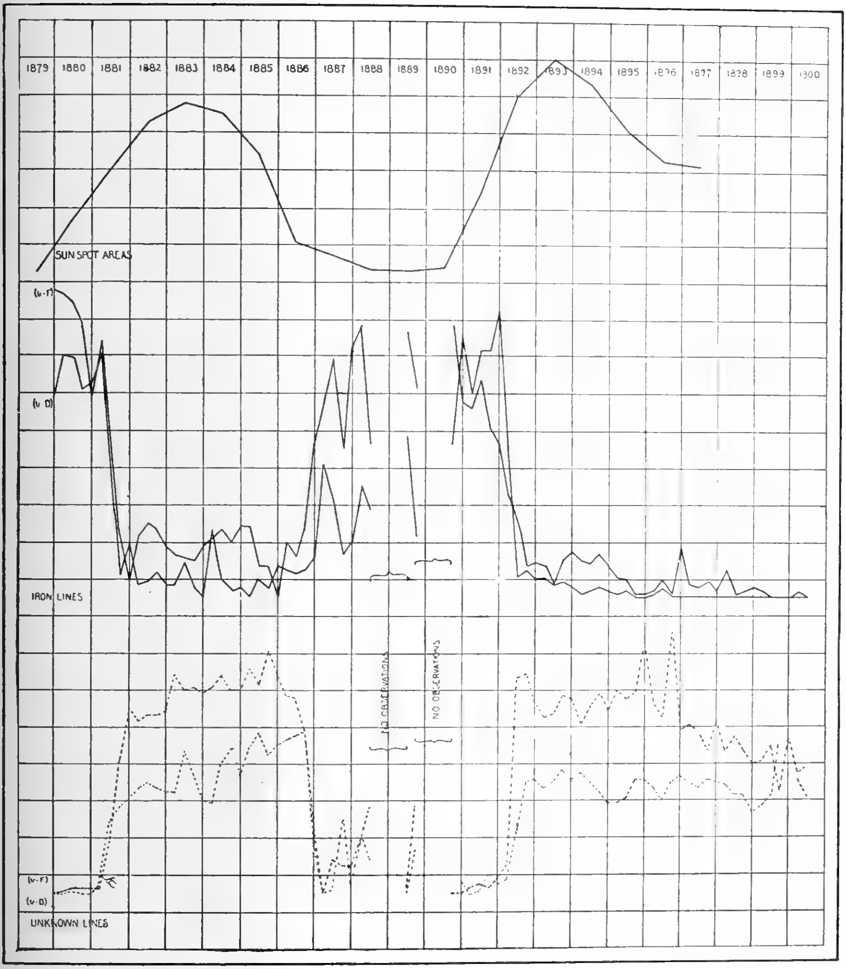
This, then, is the simple explanation of this most interesting, but at first sight paradoxical, observation of Mr. Lockyer.

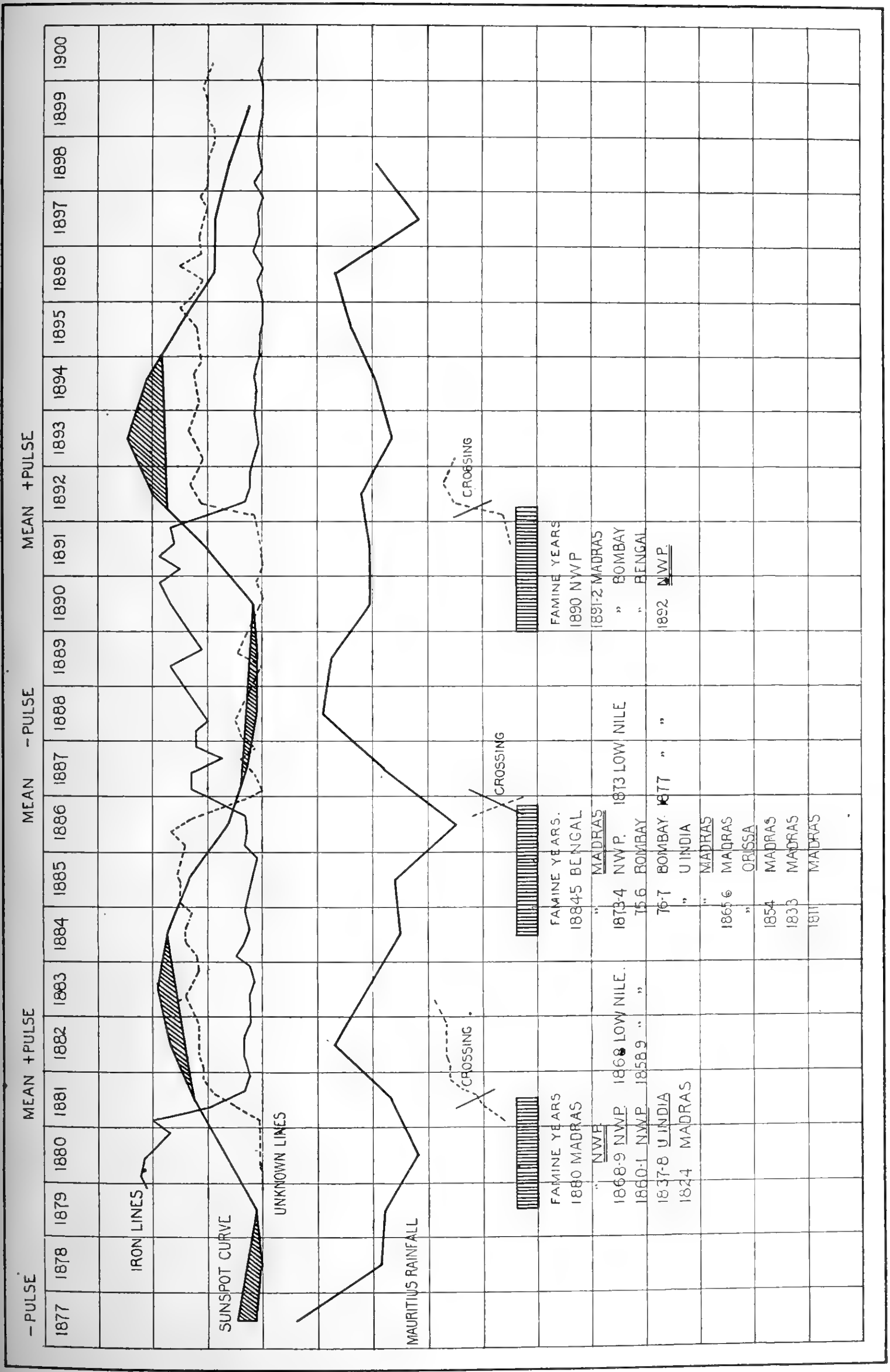
In the plate annexed (Pl. I) the upright lines are one year apart in every case; the upper curve is that showing the increase and decrease of the spots on the sun. Thus, in 1883, the sun spots had reached the greatest display at that time shown by the altitude of the curve, after which they ran down, reaching their smallest amount very nearly seven years later—about 1889—and then mounting again until, in 1893, they had again reached their maximum value, which was indeed higher than the previous one.

Now, if we look immediately under them in the same years when these were at a maximum, we shall see that the irregular lines, which represent the growth or diminution of the percentage of the whole number of lines due to iron in the spots, are at a minimum when the others are at a maximum, and are at a maximum when the others are at a minimum, and that again they have fallen to a minimum at the time of the maximum in 1893.

These lines which are at a minimum when the sun spots are at a maximum, and vice versa, are the known iron lines, but there is also a dotted curve whose maximum and minimum agree with those of the sun spots, and those are the lines whose provenance we do not know.

These are the solar phenomena. We shall see the same thing restated in its apparent connection with terrestrial phenomena by looking at Plate II, which is drawn on the same scale of years. Here we see that the close of the famine year in each case agrees with the period when the dotted line crosses the solid line; that is, where certain lines due to temperature appear or disappear. Hence, at certain periods of about eleven years we have spectroscopic evidence that there are changes of temperature in the sun, and from what follows, that these apparently coincide with the close of the famine years in India, as well as with other terrestrial phenomena. This is the important coincidence pointed out by Sir Norman Lockyer. It does not seem probable that it can be due to chance, but we must await further observations before feeling that this most interesting observation has acquired the character of entire demonstration.


1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
SUN SPOT AREAS
(v-F)
(v-D)
IRON LINES
NO OBSERVATIONS
NO OBSERVATIONS
(v-F)
(v-D)
UNKNOWN LINES



FAMINE YEARS
1880 MADRAS
" NWP.
1868-9 NWP. 1868 LOW NILE.
1860-1 NWP. 1858-9 " "
1837-8 U INDIA
1824 MADRAS

FAMINE YEARS.
1884-5 BENGAL
" MADRAS
1873-4 NWP. 1873 LOW NILE
75-6 BOMBAY
76-7 BOMBAY 1877 " "
" U INDIA
" MADRAS
1865-6 MADRAS
" ORISSA
1854 MADRAS
1833 MADRAS
1811 MADRAS

FAMINE YEARS
1890 NWP
1891-2 MADRAS
" BOMBAY
" BENGAL
1892 NWP.

THE PEKIN OBSERVATORY.[1]

The scientific world has been shocked at the looting of the Pekin Observatory by the French and German troops. The instruments are to be sent to Europe. It is greatly to General Chaffee's credit that he protested vigorously against this very unwarrantable act of vandalism. At the end of this century institutions like an observatory should at least be held sacred by civilized combatants. Our engravings represent a bronze sphere and a celestial globe of the same material, nearly 7 feet in diameter, constructed under the direction of Father Verbiest, in the seventeenth century. Our first engraving represents a bronze quarter circle sent by Louis XIV to the Emperor Kang Hi in the seventeenth century. Our fourth engraving represents the chief piece of this observatory, so rich in artistic wonders. It is a bronze astronomical instrument, vaguely recalling an equatorial. It was constructed in the thirteenth century by Ko Chon King, astronomer of the Emperor of the first Tartar dynasty and the founder of Pekin. The fifth engraving gives a general view of the astronomical instruments installed upon the terrace of the observatory by Father Verbiest while he was president of the tribunal of mathematics in 1674. Up to the present nothing has been changed in the arrangement of these apparatus, and they stand now just as they were placed by the learned missionary two hundred years ago.

The general view of the Pekin Observatory, established at the beginning of the nineteenth century near the Tartar rampart and the Temple of the Lettered, has a feudal character which more closely recalls the old gates with elliptic arches of the fortified cities of the Middle Ages than the original structures of the extreme East. It is a massive square tower, of medium height, at the top of which is observed a series of odd silhouettes. These latter are those of the instruments shown in one of our drawings. A little lower, from the left of the tower, starts a sort of shed with curved roof, and very Chinese, under which have rested, since the foundation of Pekin, a few Mongolian instruments, which are genuine artistic marvels, that our engraving can scarcely give any idea of.

This observatory is, or rather was, one of the rare curiosities of the capital of the Celestial Empire.

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[1] Reprinted from Scientific American Supplement, No. 1304, December 29, 1900.

According to those who have studied them, the accuracy of the instruments is questionable, the Chinese artisans charged with the graduation not having reproduced with exactness the models given to them.

Nowhere is there met a trace of a telescope or even of a simple tube capable of concentrating the visual rays of the observer upon a single point. The pinnule is alone employed for observations. Fortunately for science, alongside of this official observatory, the Cluny Museum of Chinese Astronomy, stand some establishments, such as Lika Wey, in which are found the most improved models of contemporary optics. For our engravings we are indebted to L'Illustration.

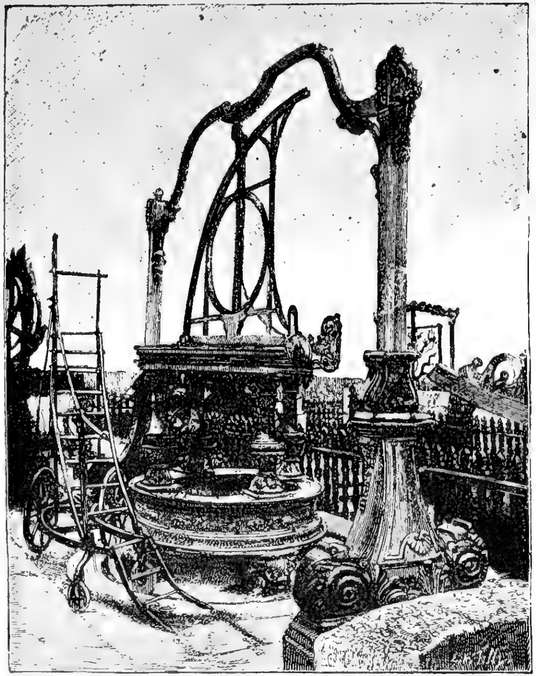

FIG. 1.—BRONZE QUADRANT SENT BY LOUIS XIV TO EMPEROR KANG HI.

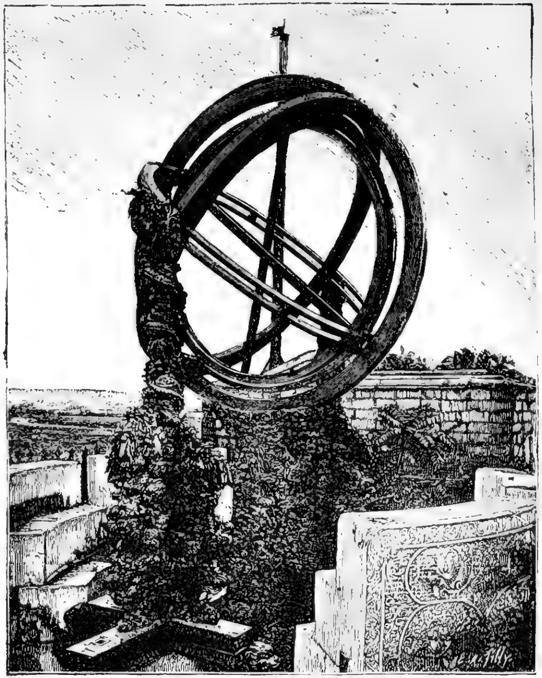

FIG. 2.—CHINESE BRONZE ARMILLARY SPHERE (SEVENTEENTH CENTURY).

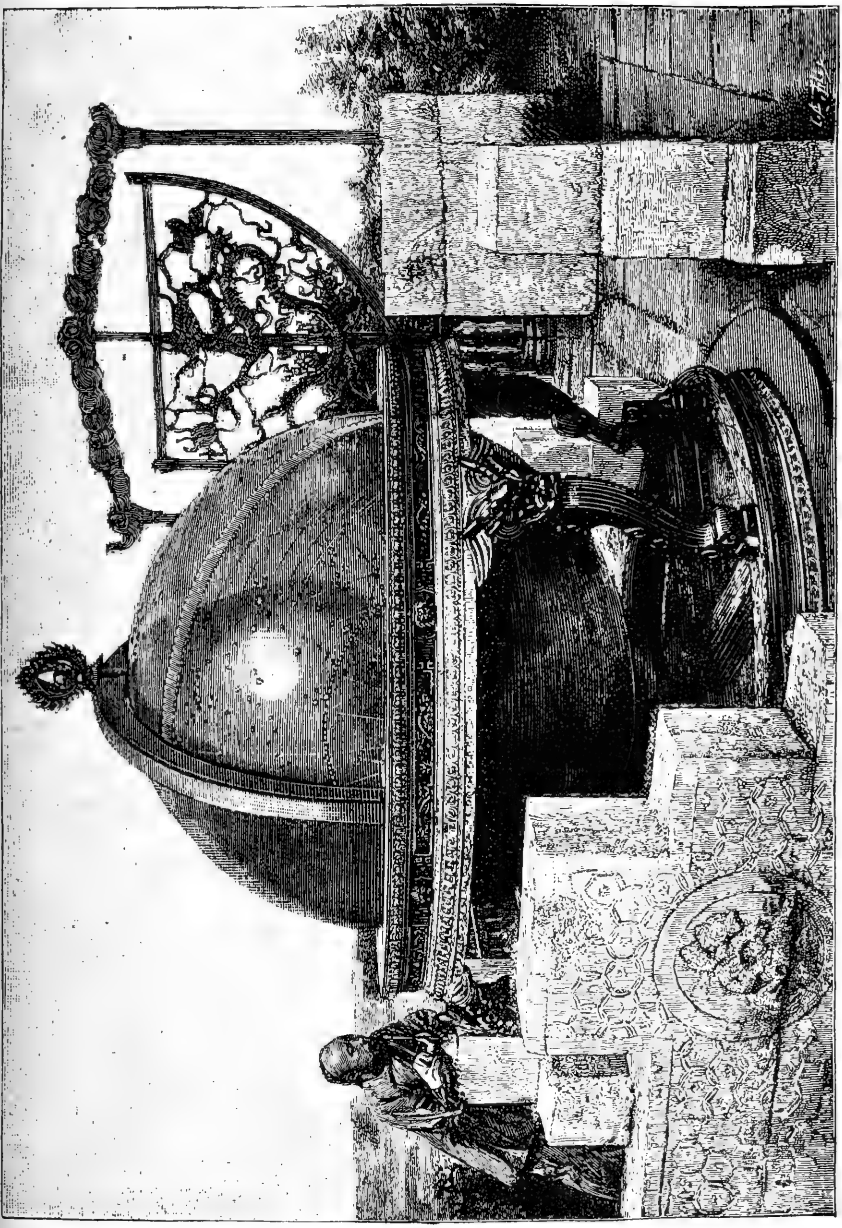

Fig. 3.—Bronze Celestial Globe (about 7 Feet in Diameter), constructed by Père Verbiest, in 1674, at the Observatory of Pekin.

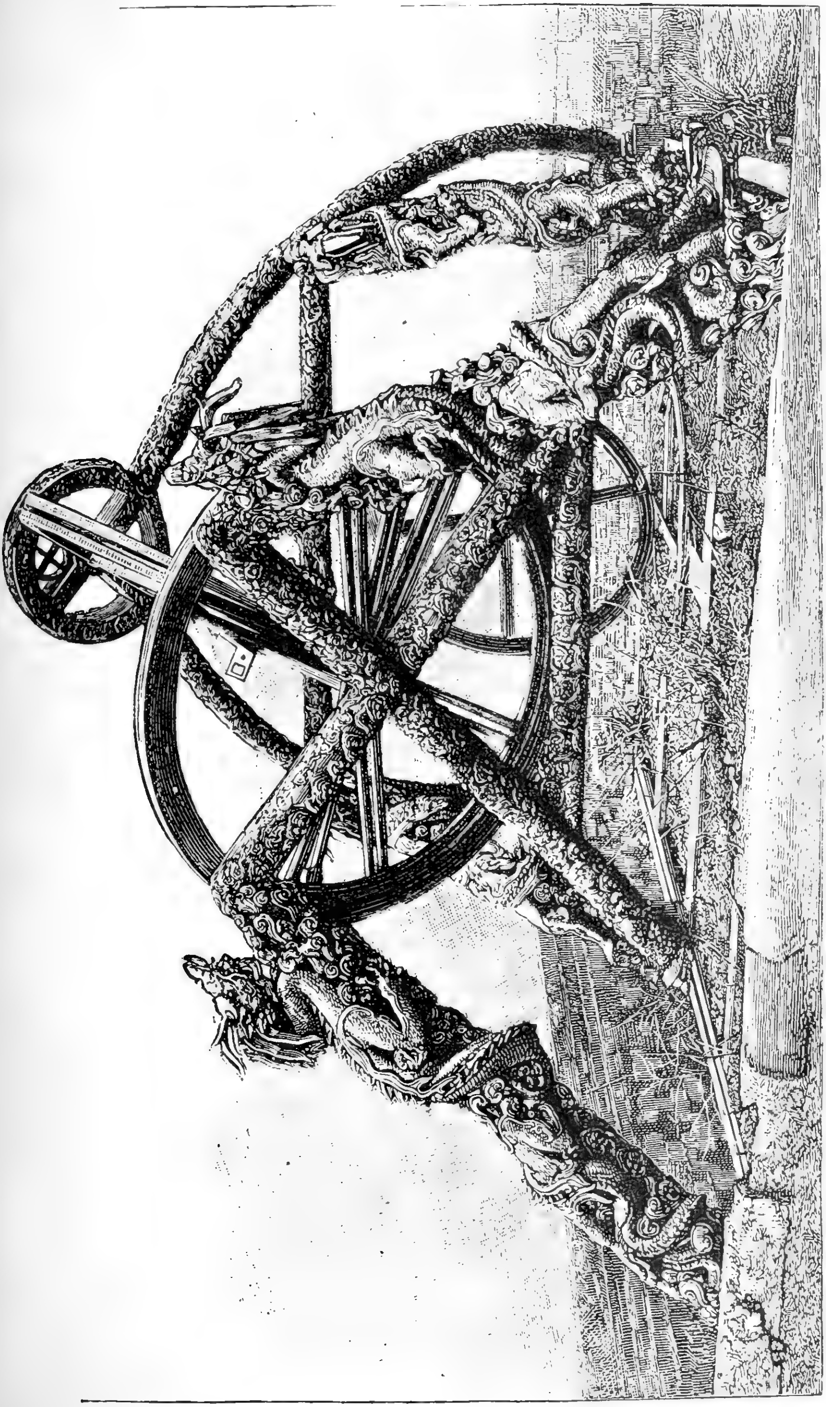

FIG. 4.—CHINESE BRONZE ASTRONOMICAL INSTRUMENT OF THE THIRTEENTH CENTURY.

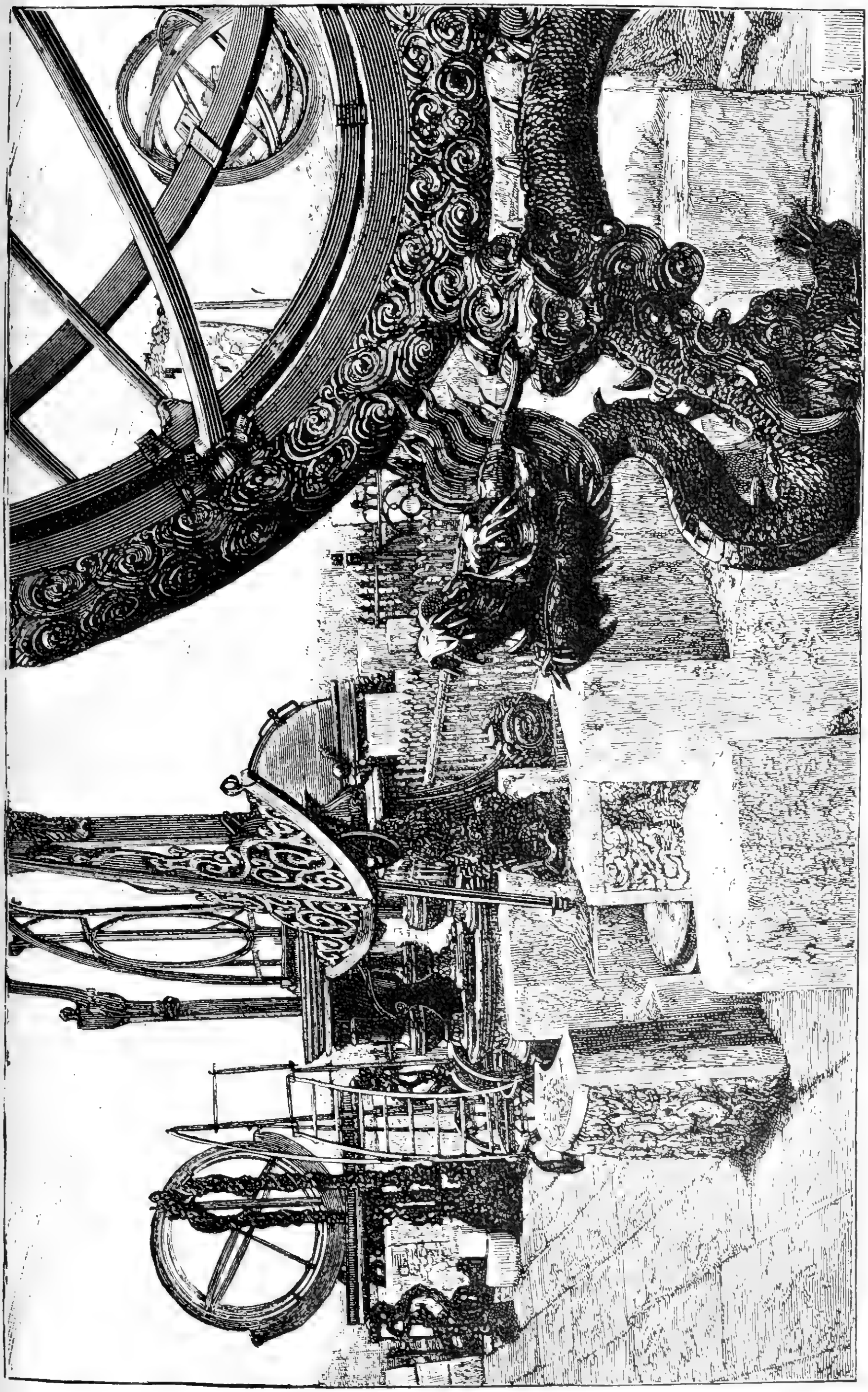

FIG. 5.—GENERAL VIEW OF THE ASTRONOMICAL INSTRUMENTS AT THE CHINESE OBSERVATORY, PEKIN.

THE PROGRESS OF AERONAUTICS.[1]

[Address of M. Janssen, president of the International Aeronautic Congress at the opening of the congress, September 15, 1900, at the Observatory of Meudon, near Paris.]

GENTLEMEN: First of all I must thank you for the great honor that you have just done me in calling me for the second time to preside at this congress. I feel it keenly and shall use my best endeavors to justify your choice.

I shall certainly be the interpreter of your sentiments in thanking the members of the committee on organization for the zeal and talent put forth by them in the arrangements for this congress, which unites in its bosom not only members of every nation and embraces the most diverse branches of aeronautics, but includes also elements of the civil and military order. I will affirm that, thanks to the elevation of intellect and of sentiments which has been shown on all hands, everything has been successfully and perfectly coordinated. This congress will certainly contribute to join in one spirit of progress and of confraternity two elements so important and so necessary to the greatness of nations.

I address the thanks of the committee on organization to our foreign colleagues who have responded with such warmth and amiability to our invitation. They have made us most happy and most proud, and we can assure them that no effort shall be spared to render their visit fruitful and agreeable. It is to be hoped that our foreign colleagues will, upon the occasion of this congress, knit ties of friendship that will not be loosed at its dissolution; for one of the fruits, perhaps the most important of the fruits, of reunions of this kind is the establishment of personal relations between men, no doubt already acquainted with one another's works and appreciative of them, but who nevertheless have never had an opportunity to see one another and to talk over the subjects of their studies.

The mind of a writer is not entirely expressed in his works. Often the best fruit of his meditations and labors is something of which he is not himself aware and which he can not record. A lively and friendly talk with a fellow-student who has followed the same career will bring these treasures up from their depths, and out of this spring new ideas, new points of view; nay, new subjects for study, enlarging and clearing the intellectual horizon.

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[1] Translated from Annuaire du bureau des longitudes pour 1901. Printed also in Revue Scientifique, September 29, 1900.

Let us add that a mutual enjoyment and a durable friendship almost invariably spring from such encounters. I do not doubt that the present congress will bring a rich harvest of these excellent fruits.

Let us now glance rapidly at the most important items of progress in aeronautics since the last congress held its meeting in Paris in 1889. The progress has been great in all directions. New and highly important subjects of study have been opened up, so that this review will necessarily be extremely incomplete, and I must beg our colleagues to pardon me some omissions which circumstances force me to make, as well as some references that will be far more summary than I would like to have them.

The siege of Paris in 1870 attracted renewed attention to the employment of balloons and of carrier pigeons in war, matters which had been laid aside in France since the First Empire. America had been about the only power which before 1870 had considered military aerostation.

The Government of the Republic soon seriously took up the creation of special military services in aerostation and in peristerophily ("colombophilie"). For this purpose the fine central institution of Chalais was founded and organized, and rapidly got systematically to work. The duty of this institution is not merely to prepare the instruments and to instruct the persons which are to be employed for the aeronautic service of our armies and military stations, but, further, to investigate all the improvements of which those engines and services are susceptible, and even to undertake studies which promise to conduct to new inventions and discoveries in the field of aerial navigation.

The majority of the other nations of the Continent very soon followed the example set by France in this respect, and indeed it must be admitted that several of them improved upon their model, either in regard to the material or in that of the mode of using it. To-day these services have acquired great importance in those nations. It even happens in Germany and Russia that the aeronautic service of war often comes to the aid of civil aerostation by lending balloons for experiments of scientific interest. Aerostation and aeronautics will therefore have no insignificant part in future wars. But already the war of the rebellion in America and, quite recently, that of the Transvaal have shown us to what advantages skillful generals can turn a well-conducted aerostatic service. Indeed, if we reflect upon the ceaseless increments in the numbers of armies, in the range of the arms, whether of artillery or of infantry, we shall readily foresee a corresponding enlargement of the theaters of war, and this, in its turn, will render indispensable both balloon reconnoissances and also more and more powerful optical instruments; nor must we forget the important service of the balloon in directing the fire of artillery.

Nevertheless, great as has been the progress which the services of military reconnoissances by aerostation have accomplished in the hands of the skillful officers who have been charged by their governments with the creation and functioning of these services, it must be confessed that important desiderata still remain. Thus it is possible now to get away from a besieged place almost without risk, but to get in again is quite another thing, for this second problem depends upon the famous one of steering a balloon, a problem which began to be solved in 1886 at Chalais-Meudon, but of which the complete solution is still in futuro.

Since 1889 this great question, how to steer a balloon, has been continually agitated. Yet we must confess that while highly interesting essays have been made, which merit all our sympathy, no decisive step has been taken. In Berlin two overbold experiments have resulted tragically. Yet experimenters have not been discouraged. M. Santo-Dumont is even now preparing to contest the prize of 100,000 francs that M. Henry Deutsch has founded at the Aero Club; and Count Zeppelin is making a new and grand attempt on the Lake of Constance with a partitioned balloon 117 meters long, moved by two petroleum engines acting on four screws.

But though the steering of balloons is the first and most important problem, yet it must not be forgotten that it is likewise of very high interest to perfect aeronautics, whether in the direction of rising to a great height, or of remaining aloft as long as possible, or of going to a point named in advance. For, aside from the immediate end pursued, these ascensions lead to improvement in the instruments and methods of aerial navigation. As examples, may be mentioned the remarkable voyage of Count de Castillon de St. Victor from Paris to Sweden, in which the balloon traveled more than 800 miles (1,300 kilometers), and that of the Count de la Vaulx, who succeeded in keeping his aerostat aloft for more than thirty hours without landing. Again, we may instance the voyage of M. Mallet, who, with the same balloon, made in a week the tour of France, landing each day. In the matter of height, the prize, or, to use the language of sport, the record belongs to Mr. Berson, attached to the Meteorological Institute of Berlin, who several times rose to 26,000 feet (8,000 meters) and once as high as 30,000 feet (9,150 meters), which is higher than the highest summits of the Himalayas. It is noteworthy that it was by the system of inhaling oxygen, which had already been tried in France, that Mr. Berson was enabled to bear the rarification of the air at such extraordinary heights.

Scientific ascensions have been much practiced in Germany, being stimulated by the Berlin Aerial Navigation Society and by the liberality of the Emperor. During the last five years no fewer than seventy-five such ascensions have been made, and the results have been discussed in the recent great work of Messrs. Asmann and Berson.

The heights attained by these balloons carrying observers are, however, necessarily limited. Even with the judicious use of oxygen, the observer has to contend with the lack of pressure of the air, which causes an expansion of all the gases contained in his body, and, notwithstanding the respiratory reparation by oxygen, the expansion may kill the man. Other means must therefore be employed to carry the investigations of science to much greater altitudes. Since the 1889 congress, the plan of Le Monnier has been realized of sending up balloons by themselves with self-registering apparatus. Here, too, there is a limit to the attainable height, but it is much greater than that of balloons carrying men. We owe to Lieutenant-Colonel Renard excellent studies and advice for constructing and managing such balloons and to Messrs. Hermite and Besançon their first employment in France. The success of these first trials and of the studies made by means of them, especially by Messrs. Violle and Cailletet, was such as to lead to the appointment of an international commission representing almost every European nation, and this commission is now holding a meeting in Paris under the presidency of Mr. Hergesel. It is easy to see that these aerial soundings, if one may call them so, become infinitely more interesting when they are made simultaneously from stations throughout a region of the earth.

But balloons are now no longer the only instruments employed for meteorological researches. The highly ingenious plan of using kites is also put into practice. These little instruments, which in China and in ancient India were accessories of public spectacles, have become, in the hands of our meteorologist, in imitation of Franklin, serious scientific apparatus. We have lately been informed that Mr. Rotch, a highly distinguished American meteorologist, has succeeded in flying one of these apparatus carrying his self-registers to a height of 15,800 feet (4,815 meters), little short of that of Mont Blanc. M. Teisserenc de Bort, our devoted colleague, who has kindly consented to give a lecture to the congress, has founded out of his contributions at Trappes, not far from the old house of Port Royal, an exceedingly interesting observatory, where meteorology is studied by widely various means, and where kites are likewise employed. One of them has lately risen to 16,900 feet (5,150 meters). In Berlin, too, at the Meteorological Institute, a new service has been instituted in which kites, both alone and combined with a balloon, are employed for the observation of atmospheric phenomena.

It was natural that balloons, which are only rendered possible by the atmosphere, should at first be used for the study of the atmosphere. But now they begin to look higher, and the heavens will confer upon them a new and honorable office. For while there are astronomical investigations which require great instruments of the utmost stability, there is another class of phenomena which only need to be noted as taking place. Of this number are, for example, the apparitions of comets, shooting stars, and eclipses. This extremely interesting application of the balloon dates from an earlier period; but it had long been neglected. I was always struck with its importance; and in 1898, when the Leonid shower was expected, M. Hausky made an ascension under my direction, and obtained interesting results. Last year, at my request, these observations were repeated in Paris by Mlle. Klumpke and by Messrs. Tikhoff, the Count de la Vaulx, Mallet, and de Fonvielle. Ascensions were also made at St. Petersburg, at Strassburg, and in England for the same purpose. The Leonid shower of next November will have a quite special interest. I hope it will not pass unobserved.

I can not close this recapitulation without at least referring to work in the direction of machines to be sustained and propelled exclusively by forces which they produce. The most remarkable results obtained in this direction are unquestionably those of Mr. Langley, correspondent of the Institute of France and Secretary of the Smithsonian Institution at Washington. Independently of the fine and profound researches of this scientist upon the resistance of the air, Mr. Langley has constructed an aeroplane which has progressed and has sustained itself during a time notably longer than any of the apparatus previously constructed. Dr. Richet has repeated and varied these fine experiments on the shore of the Mediterranean. Time is wanting to speak of other work upon aeroplanes, but it is impossible not to mention the endeavors of M. Ader to construct a flying bird, or not to recall the cruel accident which caused the death of a scientist of great merit. I need not tell you that I refer to the unfortunate Lilienthal, whose works on the properties of curved surfaces in aeronautics will not allow the world to forget his name.

While we are speaking of the dead, permit me to devote a word in memory of the scientists and aeronauts whom we have lost: Eugène Godard, the elder, an experienced aeronaut, the constructor of the balloons of the siege at the railway stations of Orleans and of the East, whom I personally have cause to remember with gratitude for the excellent counsels he gave me at the moment of my departure from Paris, December 2, 1870, with the balloon Volta; Hureau de Villeneuve, founder of the journal L'Aéronaute and one of the founders of the Society for Aerial Navigation; Gaston Tissandier, too, patriotic aeronaut of the army of the Loire, the witness to the terrible drama of the Zenith; the author, with his brother Albert, of experiments upon using electricity to steer balloons, and founder, also, with Albert, of the interesting journal La Nature. And still I have to mention Coxwell, the aeronaut of Mr. Glaisher, whose noble and green old age we salute to day.

Such, gentlemen, is the picture, necessarily very incomplete, of the state of aeronautics at this moment. Is it not, however, sufficient to show how remarkable has been the progress accomplished in the decennial period it covers?

It must, however, be confessed that aeronautics has not, generally speaking, been endowed and encouraged by the powers that be as it should have been in order to attract to it all the varied orders of capability which it demands and to furnish the resources necessary for its researches and indispensable for its experiments. Let us not deceive ourselves. Some nation will have the wisdom to make a great advance in this direction, and will thereby acquire a power and advantages of which the results can not to-day be foreseen. Thus, in the ancient world certain great minds felt beforehand the vast importance of the part which the liquid element was destined to play in the relations between peoples. Themistocles said, "He who shall make himself master of the sea is destined to become master of the land." This flash of genius, true already even then, has by this time attained such a degree of truth as to be obvious. What supremacy has not our neighbor been able to gain from her fleets, which dominate the seas which are tied round the continents. and which are mistresses of almost all the telegraphic connections of the globe? Now, if the ocean has given this power to the nation that has been wise enough to seize it, what will be the power of the coming mistress of the atmosphere? The sea has its limits and its frontiers; the atmosphere knows no such thing. The sea offers a mere surface to the navigator; the aeronaut can profit by the whole depth of the atmosphere. The sea severs the continents; the air unites everything and dominates everything. [That the sea separates, while the air unites, is a proposition the sense of which may easily escape the reader. The sea renders it difficult to pass, for example, between an island and the mainland, and a number of vessels sailing round and round the island could cut off any attempt to make the passage. Through the air, on the other hand, there will always be a path from any one point on the earth's surface to any other, and no matter how vigilant a patrol were instituted there would be plenty of room to pass with impunity.] When that mistress, whatever nation she may be, accedes, in what sense will the frontiers between one State and another any longer exist, while aerial fleets sail over them with complete impunity? True, the day of the realization of all that seems remote enough; yet it is probable, in the light of experience, that it is less remote than it seems. It is quite certain that come it eventually will, and that man will not give over his ambition before having made a complete conquest of the atmosphere. It is the part of good sense to consider beforehand what are destined to be the consequences of that revolution upon the economic conditions of life and upon the relations between nations. Let us hope that that conquest, which supposes an all-powerful industry and a transcendent science, will come when civilization has reached such an elevation that it will recognize justice, right, and peace as alone concordant with the welfare of mankind. It may be that this wish is vain, but at any rate the discoveries, when they come, will present one aspect under which their benefits will be undeniable and their fruits will be unmixed with any bitter; and that is their scientific aspect. When man takes possession of this new estate he will garner as his first harvest a complete meteorology, phenomena, and cause, through the whole depth of the atmosphere, and this knowlege, be sure, will have consequences that we can hardly imagine to-day. Agriculture, industry, navigation, will be transformed. The same knowledge will be utilized the better to avail one's self of the energy now wasted in the tides, in great waterfalls, and in the solar energy which in a given time is scattered over the earth in six hundred thousand times the amount of what is brought up from coal mines. Such will be the benefits which posterity will reap from those pacific conquests which I love to contemplate. Here, at least, we have no reason for other sentiments than those of joy and admiration. Happy are we to have been called to contribute our stone to such an edifice; happier still our posterity, who shall have the glory of crowning it. This seizure of a domain from which nature seemed to have closed all access will certainly constitute, by the constancy and intensity of the efforts it will have cost, by the discoveries and marvelous inventions that it will have provoked, one of the highest titles to glory of which the human race will be able to boast.

LORD RAYLEIGH ON FLIGHT.[1]

The first Friday evening meeting for this season of the members of the Royal Institution took place last night, when Lord Rayleigh delivered a discourse on "Flight." The Duke of Northumberland was in the chair, and among the large audience were Lord and Lady Kelvin, Sir Frederick Bramwell, Mr. A. J. Balfour, Sir Frederick Abel, Sir William Crookes, Sir James Crichton-Browne, Professor Dewar, Mr. Justice Stirling, Dr. J. H. Gladstone, Mr. Hiram Maxim, and Sir H. T. Wood.

Lord Rayleigh first considered the question what people generally meant when they spoke of a flying machine, and concluded that size had a great deal to do with their conception, which was usually of a machine big enough to carry a man by whom it could be controlled. The main problem of the flying machine was the problem of the aeroplane. What were the forces that acted on a plane exposed to the wind? This was also the vital problem of kites, of which he mentioned some of the practical applications by Franklin, Archibald, Baden-Powell, and others; but kites were always anchored to the ground, and as soon as we cast ourselves adrift from the ground the problem became difficult, for it was then necessary to consider how maintenance in the air could be managed. Now some birds seemed to maintain themselves in the air with little effort. What was the nature of the "soaring" or "sailing flight" by which a big bird maintained itself with but little flapping of the wings? There had been much discussion about this point, often foolish because of misunderstandings between the disputants. However, the science of mechanics enabled it to be laid down with certainty that a bird could no more maintain itself without motion of the wings in a uniform wind moving horizontally than in air at perfect rest. It was entirely a question of relative motion. If, then, a bird was seen to be maintaining itself without flapping it was certain the air was not moving horizontally and uniformly. But there might be rising currents of air upon which it was supported, and these were much more common than was often supposed. In other cases where it was difficult to imagine the existence of such currents an explanation might be sought in the nonuniformity of the wind, for it was mechanically possible for a bird just at the point of transition between two different strata of wind to maintain its position by taking advantage of the different velocities. The albatross, he believed, did so. Langley, again, had pointed out how the bird could turn to account the internal work of the wind by taking

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[1] From London Times, January 20, 1900.

advantage of its gustiness. Leaving this subject, the lecturer discussed the general question of the action of the wind on an aeroplane. He first showed one or two experiments illustrating the curious effects that might be obtained from a plane exposed obliquely to wind. In one of these it was seen that a light piece of sheet brass, evenly pivoted in and nearly filling up an aperture through which air was issuing under pressure, tended to set itself square to the aperture so as to block it as much as possible, but, if started, it continued to rotate in either direction, emitting a roaring sound. This phenomenon had never been properly explained, nor had the somewhat analogous action of a piece of card, which, when dropped, reached the ground with a rotatory motion. As to the pressure of the wind on a plane surface, if the latter was falling vertically at the rate, say, of 4 miles an hour, and also moving horizontally at, say, 20 miles an hour, did the horizontal motion make a difference to the pressure that existed at its under surface? It might be argued that it did not; but the argument was fallacious, and the truth was that the horizontal motion much increased the pressure under a vertically falling plane, a fact on which depended the possibility of flight, natural and artificial. Lord Rayleigh showed how this point might be illustrated, and even investigated, by means of a simple variation of the ordinary windmill. This was a light wheel having six vanes, each of which could be set at any desired angle, and it was used by setting four at a particular angle and finding at what angle the other two must be placed so as to compensate the rotation of the wheel produced by the former when it was moved quickly through the air. He next observed that not only was there pressure underneath a bird's wing or an aeroplane, but that the suction above was not an unimportant matter, and he performed an experiment to show the reality of this suction, about which he said there had been some skepticism. Turning to flight on a large scale, he remarked that it was a natural question to ask, Was it possible for a man to raise himself from the ground by working a screw with his own muscular power only? The investigation was not difficult, and the answer was that it was quite impracticable for him to do so. Artificial flight was a question of the speed of the horizontal motion. A bird did not use a revolving mechanism like a screw to propel itself, but he had no doubt that a revolving mechanism was the most suitable for artificial flying machines. Whether the difficulties of these would be surmounted he did not know, but he was disposed to agree with Mr. Maxim that it was mainly a question of some time and much money. Still, he did not think flight would ever be a safe mode of conveyance for those who were desirous of going out for a day's shopping, for it was hard to see how alighting on the ground could ever be rendered quite free from danger. But, as Mr. Maxim once remarked, the first use of flying machines would be for military purposes, and they had not yet succeeded in making war quite safe.

THE LANGLEY AËRODROME.

I. NOTE PREPARED FOR THE CONVERSAZIONE OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, NEW YORK CITY, APRIL 12, 1901.

What is popularly known as the "flying machine" is literally a machine, without gas to support it, in no way resembling a balloon, and which its inventor has called the Aërodrome. The Aërodrome (from words signifying "air runner") is, then, the name given to this apparatus by Mr. Langley to indicate the principle of its action, which in no way resembles that of a balloon that floats, because it is lighter than the air, while the aërodrome is hundreds of times heavier than the air. The weighty machine owes its support to another principle—that is, to the *rapidity* with which it runs over the air, like a skater on thin ice. The balloon in a calm remains indefinitely suspended over one spot. This machine, built almost entirely of steel, is far heavier in relation to the air than a ship of solid lead would be in relation to the water, and could not remain in the air if still.

The essence of its action, then, is in its motion, without which it could not remain suspended. It is moved rapidly by a steam engine, carrying its own fuel and its water supply, by which it can be kept up indefinitely, while it is also, and by the necessity of its own action, rapidly advancing.

This may all be admitted as probably true in theory, but it is not generally known that this has actually been done.

The two large photographs are each about one-third the full size of one of several working models,[1] each of which is driven by a steam engine of over 1¼ horsepower. This and other like models have repeatedly flown distances of over half a mile, at a speed of from 20 to 30 miles an hour.

This actual result has not been advertised, and is comparatively little known, though these models are believed to have done something absolutely new in the history of the world. They are the product of a great many years of assiduous labor, and represent the condition of the experiments in Mr. Langley's hands up to the close of the year 1896, since which time he has made no public statement of his work, which is understood to be still going on in connection with experiments for the War Department in demonstrating the possible uses of the future aërodrome as an engine of war.

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[1] Here shown in reduced size, Plates IV, V.

Reverting to the present models, they represent a machine whose weight is about 30 pounds, one-fourth of which is contained in the engine and machinery, which is of unexampled lightness. Within the small body, seen in the photograph suspended under the main rod, is contained everything for generating 1¼ (brake) horsepower, the total weight of fire grate, boiler, and every accessory being less than 7 pounds. The engine, with its cylinders, pistons, and every moving part, weighs 26 ounces. This puts in motion the propellers, which, turning at a rate of between 800 and 1,200 revolutions per minute, drives the aërodrome at a speed which varies greatly, according to the inclination given to the motionless "wings."

Mr. Langley, after a great many years of preliminary experiment on supporting surfaces, which he has described in his "Experiments in aërodynamics," first made a remarkable, and to the engineer, most paradoxical statement; namely, that in such aërial navigation as was there shown to be possible, under certain definite conditions the power required would in theory *diminish* indefinitely as the speed increased, and that it would actually diminish in practice up to a certain limit.

This statement, which has since been called "Langley's law," is justified in practice, but the conditions which give this increase of speed with decrease of power are limited by others which demand that the flight should be made in safety and without that danger of accident which might come in applying rigorously exact theoretical conclusions without regard to the security of the flight. The actual speed which was obtained, then, was under conditions where security was chiefly sought.

In the experiments which have hitherto been made, safety has accordingly been the first consideration, and the "wings," or rather the motionless supporting surfaces, have been given such an inclination as to cause the speed to be limited to between 20 and 30 miles an hour. The machine has actually traveled very much faster than this, but its higher speeds have not been measured.

The aërodrome was launched from a specially constructed house boat on the Potomac in a secluded spot about 30 miles below Washington, and was supplied with water for a short course lest it should, in its uncontrolled flight, go altogether out of reach, and lose itself in the neighboring Virginia forests. The idea of making the flight over water from a house boat or raft may appear obvious when once stated, but like many simple results it was only reached after long experiment with other methods, and its utility has since been shown by its employment by others. There was no other reason why it should not fly for an indefinite time except the waste of water, which in the model had no provision for its renewal by condensation. This aërodrome, which is one of several which have flown considerable distances, performed this first flight on May 6, 1896, at a private trial of which Dr.

Alexander Graham Bell was the only witness. His contemporary statement may be found in the Comptes Rendus of the French Institute, CXXII, May 26, 1896.

A similar statement by him in the pages of Nature, May 28, 1896, vol. 54, is as follows:

> Through the courtesy of Mr. S. P. Langley, Secretary of the Smithsonian Institution, I have had on various occasions the privilege of witnessing his experiments with aërodromes, and especially the remarkable success attained by him in experiments made on the Potomac River on Wednesday, May 6, which led me to urge him to make public some of these results.
>
> I had the pleasure of witnessing the successful flight of some of these aërodromes more than a year ago, but Professor Langley's reluctance to make the results public at that time prevented me from asking him, as I have done since, to let me give an account of what I saw.
>
> On the date named two ascensions were made by the aërodrome, or so-called "flying machine," which I will not describe here further than to say that it appeared to me to be built almost entirely of metal and driven by a steam engine, which I have understood was carrying fuel and a water supply for a very brief period, and which was of extraordinary lightness.
>
> The absolute weight of the aërodrome, including that of the engine and all appurtenances, was, as I was told, about 25 pounds, and the distance from tip to tip of the supporting surfaces was, as I observed, about 12 or 14 feet.
>
> The method of propulsion was by aërial screw propellers, and there was no gas or other aid for lifting it in the air except its own internal energy.
>
> On the occasion referred to the aërodrome at a given signal started from a platform about 20 feet above the water and rose at first directly in the face of the wind, moving at all times with remarkable steadiness, and subsequently swinging around in large curves of perhaps a hundred yards in diameter, and continually ascending until its steam was exhausted, when, at a lapse of about a minute and a half and at a height which I judged to be between 80 and 100 feet in the air, the wheels ceased turning, and the machine, deprived of the aid of its propellers, to my surprise did not fall, but settled down so softly and gently that it touched the water without the least shock, and was in fact immediately ready for another trial.
>
> In the second trial, which followed directly, it repeated in nearly every respect the actions of the first, except that the direction of its course was different. It ascended again in the face of the wind, afterwards moving steadily and continually in large curves accompanied with a rising motion and a lateral advance. Its motion was, in fact, so steady that I think a glass of water on its surface would have remained unspilled. When the steam gave out again it repeated for a second time the experience of the first trial when the steam had ceased, and settled gently and easily down. What height it reached at this trial I can not say, as I was not so favorably placed as in the first, but I had occasion to notice that this time its course took it over a wooded promontory, and I was relieved of some apprehension in seeing that it was already so high as to pass the tree tops by 20 or 30 feet. It reached the water one minute and thirty-one seconds from the time it started, at a measured distance of over 900 feet from the point at which it rose.
>
> This, however, was by no means the length of its flight. I estimated from the diameter of the curve described, from the number of turns of the propellers, as given by the automatic counter, after due allowance for slip, and from other measures, that the actual length of flight on each occasion was slightly over 3,000 feet. It is at least safe to say that each exceeded half an English mile.
>
> From the time and distance it will be noticed that the velocity was between 20 and 25 miles an hour, in a course which was constantly taking it "up hill." I may add

that on a previous occasion I have seen a far higher velocity attained by the same aërodrome when its course was horizontal.

I have no desire to enter into detail further than I have done, but I can not but add that it seems to me that no one who was present on this interesting occasion could have failed to recognize that the practicability of mechanical flight had been demonstrated.

ALEXANDER GRAHAM BELL.

No adequate pictures have been made of the actual flight of the aërodrome, which from the rapidity of its motion required very special preparation; but Dr. Bell made on the uniquely interesting occasion of the first flight some photographs with a small pocket camera, from which pictures have been taken. They are necessarily inadequate as pictures, but they distinctly exhibit the aërodrome as a distant and elevated object in the air. (Pl. VI.)

II. PAPER FROM M'CLURE'S MAGAZINE.

[To partly satisfy a public curiosity which could not be altogether gratified, Mr. Langley wrote a wholly popular and untechnical account of the work which had gone on up to June, 1896, in McClure's Magazine. By the courtesy of the publishers he has been enabled to make considerable extracts from this article, which are reprinted here.

Attached to the present paper is an entirely mechanical reproduction of an instantaneous photograph (Plate VI) taken by Dr. Alexander Graham Bell, showing the aërodrome in actual flight, and which has never before been published. The original was taken with a small pocket camera and has been very greatly enlarged for the present article. It is necessarily inadequate, considered as a picture, but it is uniquely interesting as giving a distinct exhibit of the aërodrome as a distant elevated object in the air. The woods beneath it are the trees on the secluded island of Chopawamsic, near Quantico, on the Virginia shore of the Potomac River about 30 miles below Washington, where the flight occurred on May 6, 1896.]

THE "FLYING MACHINE."[1]

* * * Nature has made her flying machine in the bird, which is nearly a thousand times as heavy as the air its bulk displaces, and only those who have tried to rival it know how inimitable her work is, for the "way of a bird in the air" remains as wonderful to us as it was to Solomon, and the sight of the bird has constantly held this wonder before men's eyes and in some men's minds, and kept the flame of hope from utter extinction, in spite of long disappointment. I well remember how, as a child, when lying in a New England pasture, I watched a hawk soaring far up in the blue, and sailing for a long time

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[1] Reprinted, by permission, from McClure's Magazine, June, 1897. See also Story of Experiments in Mechanical Flight, by S. P. Langley, in Smithsonian Report, 1897, pp. 169–181.

without any motion of its wings, as though it needed no work to sustain it, but was kept up there by some miracle. But, however sustained, I saw it sweep, in a few seconds of its leisurely flight, over a distance that to me was encumbered with every sort of obstacle, which did not exist for it. The wall over which I had climbed when I left the road, the ravine I had crossed, the patch of undergrowth through which I had pushed my way—all these were nothing to the bird, and while the road had only taken me in one direction, the bird's level highway led everywhere, and opened the way into every nook and corner of the landscape. How wonderfully easy, too, was its flight! There was not a flutter of its pinions as it swept over the field, in a motion which seemed as effortless as that of its shadow.

After many years and in mature life, I was brought to think of these things again, and to ask myself whether the problem of artificial flight was as hopeless and as absurd as it was then thought to be. Nature had solved it, and why not man? Perhaps it was because he had begun at the wrong end, and attempted to construct machines to fly before knowing the principles on which flight rested. I turned for these principles to my books and got no help. Sir Isaac Newton had indicated a rule for finding the resistance to advance through the air, which seemed, if correct, to call for enormous mechanical power, and a distinguished French mathematician had given a formula showing how rapidly the power must increase with the velocity of flight, and according to which a swallow, to attain a speed it is now known to reach, must be possessed of the strength of a man.

Remembering the effortless flight of the soaring bird, it seemed that the first thing to do was to discard rules which led to such results, and to commence new experiments, not to build a flying machine at once, but to find the principles upon which one should be built; to find, for instance, with certainty by direct trial how much horsepower was needed to sustain a surface of given weight by means of its motion through the air.

Having decided to look for myself at these questions, and at first hand, the apparatus for this preliminary investigation was installed at Allegheny, Pa., about ten years ago. It consisted of a "whirling table" of unprecedented size, mounted in the open air, and driven round by a steam engine, so that the end of its revolving arm swept through a circumference of 200 feet, at all speeds up to 70 miles an hour. At the end of this arm was placed the apparatus to be tested, and, among other things, this included surfaces disposed like wings, which were hung from the end of the arm and dragged through the air till its resistance supported them as a kite is supported by the wind. One of the first things observed was that if it took a certain strain to sustain a properly disposed weight while it was stationary in the air, then not only to suspend it but to advance it rapidly at the same time took less strain than in the first case. A plate of brass weighing 1 pound, for instance, was hung from the end of the arm by a spring, which was drawn out till it registered that pound weight when the arm was still. When the arm was in motion, with the spring pulling the plate after it, it might naturally be supposed that, as it was drawn faster, the pull would be greater, but the contrary was observed, for under these circumstances the spring *contracted* till it registered less than an ounce. When the speed increased to that of a bird, the brass plate seemed to float on the air, and not only this, but taking into consideration both the strain and the velocity, it was found that absolutely less power was spent to make the plate move fast than slow, a result which seemed very extraordinary, since in all methods of land and water transport a high speed costs much more power than a slow one for the same distance.

These experiments were continued for three years, with the general conclusion that by simply moving any given weight of this form fast enough in a horizontal path it was possible to sustain it with less than one-twentieth of the power that Newton's rule called for. In particular it was proved that if we could insure horizontal flight without friction, about 200 pounds of such plates could be moved through the air at the speed of an express train and sustained upon it, with the expenditure of 1 horsepower, sustained, that is, without any gas to lighten the weight, or by other means of flotation than the air over which it is made to run, as a swift skater runs safely over thin ice, or a skipping stone goes over water without sinking, till its speed is exhausted. This was saying that, so far as power alone was concerned, mechanical flight was theoretically possible with engines we could then build, since I was satisfied that boilers and engines could be constructed to weigh less than 20 pounds to the horsepower, and that 1 horsepower would, in theory at least, support nearly ten times that if the flight were *horizontal*. Almost everything, it will be noticed, depends on this; for if the flight is downward it will end at the ground, and if upward the machine will be climbing an invisible hill, with the same or a greater effort than every bicycler experiences with a real one. Speed, then, and this speed expended in a horizontal course, were the first two requisites. This was not saying that a flying machine could be started from the ground, guided into such flight in any direction, and brought back to earth in safety. There was, then, something more than power needed; that is, skill to use it, and the reader should notice the distinction. Hitherto it had always been supposed that it was wholly the lack of mechanical power to fly which made mechanical flight impossible. The first stage of the investigation had shown how much, or rather how little, power was needed in theory for the horizontal flight of a given weight, and the second stage, which was now to be entered upon, was to show first how to procure this power with as little weight as possible, and, having it, how by its means to acquire this horizontal flight in practice; that is, how to acquire the *art* of flight or how to build a ship that could actually navigate the air.

One thing which was made clear by these preliminary experiments, and made clear nearly for the first time, was that if a surface be made to advance rapidly, we secure an essential advantage in our ability to support it. Clearly we want the advance to get from place to place; but it proves also to be the only practicable way of supporting the thing at all, to thus take advantage of the inertia of the air, and this point is so all-important that we will renew an old illustration of it. The idea in a vague sense is as ancient as classical times. Pope says:

> Swift Camilla scours the plain,
> Flies o'er the unbending corn, and skims along the main.

Now, is this really so in the sense that a Camilla, by running fast enough, could run over the tops of the corn? *If* she ran fast enough, yes; but the idea may be shown better by the analogous case of a skater who can glide safely over the thinnest ice if the speed is sufficient.

Think of a cake of ice of any small size, suppose a foot square. It possesses (like everything else in nature) inertia or resistance to displacement, and this will be less or more according to the mass moved. If the skater stands during a single second upon this small mass it will sink under him until he is perhaps waist deep in the water, while a cake of the same width but twice the length will yield only about half as readily to his weight. On this he will sink only to his knees, we may suppose, while if we think of another cake ten times as long as the first—that is, 1 foot wide and 10 feet long—we see that on this, during the same second, he will not sink above his feet. This is all plain enough; but now suppose the long cake to be divided into ten distinct portions, then it ought to be equally clear that the skater who glides over the whole in a second distributes his weight over just as much ice as though all ten were in one solid piece. So it is with the air. Even the viewless air possesses inertia; it can not be pushed aside without some effort; and while the portion which is directly under the airship would not keep it from falling several yards in the first second, if the ship goes forward so that it runs or treads on thousands of such portions in that time, it will sink in proportionately less degree; sink perhaps only through a fraction of an inch.

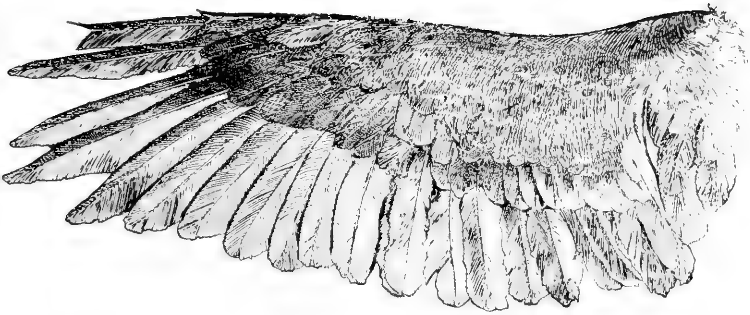
Speed, then, is indispensable here. A balloon, like a ship, will float over one spot in safety, but our flying machine must be in motion to sustain itself, and in motion, in fact, before it can even begin to fly.

Perhaps we may more fully understand what is meant by looking at a boy's kite. Everyone knows that it is held by a string against the wind, which sustains it, and that it falls in a calm. Most of us remember that even in a calm, if we run and draw it along it will still keep up, for what is required is motion relative to the air, however obtained.

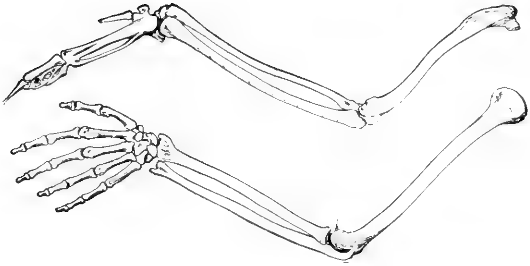
It can be obtained without the cord if the same pull is given by an engine and propellers strong enough to draw it and light enough to be attached to and sustained by it. The stronger the pull and the quicker the motion, the heavier the kite may be made. It may be, instead of a sheet of paper, a sheet of metal even, like the plate of brass which has already been mentioned as seeming, when in rapid motion, to float upon the air, and, if it will make the principle involved more clear, the reader may think of our aërodrome as a great steel kite made to run fast enough over the air to sustain itself, whether in a calm or in a wind, by means of its propelling machinery, which takes the place of the string.

And now, having the theory of the flight before us, let us come to the practice. The first thing will be to provide an engine of unprecedented lightness that is to furnish the power. A few years ago an engine that developed a horsepower weighed nearly as much as the actual horse did. We have got to begin by trying to make an engine which shall weigh, everything complete, boiler and all, not more than 20 pounds to the horsepower, and preferably less than 10; but even if we have done this very hard thing we may be said to have only fought our way up to an enormous difficulty, for the next question will be how to use the power it gives so as to get a horizontal flight. We must then consider through what means the power is to be applied when we get it, and whether we shall, for instance, have wings or screws. At first it seems as though nature must know best, and that since her flying models, birds, are exclusively employing wings, this is the thing for us; but perhaps this is not the case. If we had imitated the horse or the ox, and made the machine which draws our trains walk on legs we should undoubtedly never have done as well as with the locomotive rolling on wheels; or if we had imitated the whale, with its fins, we should not have had so good a boat as we now have in the steamship with the paddle wheels or the screw, both of which are constructions that nature never employs. This is so important a point that we will look at the way nature got her models. Here is a human skeleton, and here one of a bird, drawn to the same scale (Pl. I). Apparently nature made one out of the other, or both out of some common type, and the closer we look the more curious the likeness appears.

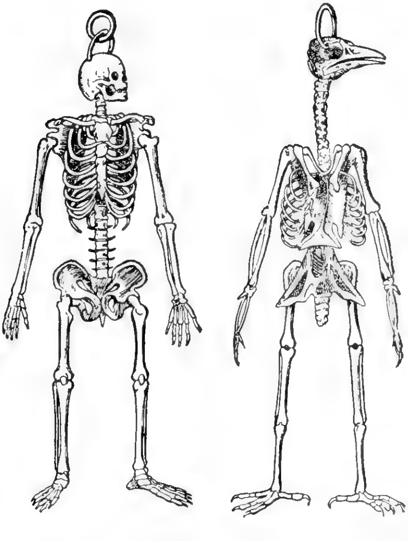
Here is a wing from a soaring bird, here the same wing stripped of its feathers, and here the bones of a human arm, on the same scale. Now, on comparing them, we see still more clearly than in the skeleton that the bird's wing has developed out of something like our own arm.



A WING FROM A SOARING BIRD.



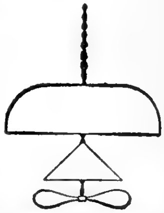
THE BONES OF A BIRD'S WING AND THE BONES OF A HUMAN ARM, DRAWN TO THE SAME SCALE, SHOWING THE CLOSE RESEMBLANCE BETWEEN THEM.



THE SKELETON OF A MAN AND THE SKELETON OF A BIRD, DRAWN TO THE SAME SCALE, SHOWING THE CURIOUS LIKENESS BETWEEN THEM.

First comes the humerus, or principal bone of the upper arm, which is in the wing also (Pl. I). Next we see that the forearm of the bird repeats the radius and ulna, or two bones of our own forearm, while our wrist and finger bones are modified in the bird to carry the feathers, but are still there. To make the bird, then, nature appears to have taken what material she had in stock, so to speak, and developed it into something that would do. It was all that nature had to work on, and she has done wonderfully well with such unpromising material; but anyone can see that our arms would not be the best thing to make flying machines out of, and that there is no need of our starting there when we can start with something better and develop that. Flapping wings might be made on other principles, and perhaps will be found in future flying machines, but the most promising thing to try seemed to me to be the screw propeller.

Some twenty years ago, Penaud, a Frenchman, made a toy, consisting of a flat, immovable, sustaining wing surface, a flat tail, and a small propelling screw. He made the wing and tail out of paper or silk, and the propeller out of cork and feathers, and it was driven directly by strands of india-rubber twisted lamplighter fashion, and which turned the wheel as they untwisted.



Penaud's flying toy (one-eighth of actual size).

The great difficulty of the task of creating a flying machine may be partly understood when it is stated that no machine in the whole history of invention, unless it were this toy of Penaud's, had ever, so far as I can learn, flown for even ten seconds; but something that will actually fly must be had to teach the art of "balancing."

When experiments are made with models moving on a whirling table or running on a railroad track, these are *forced* to move horizontally and at the same time are held so that they can not turn over; but in free flight there will be nothing to secure this, unless the air ship is so adjusted in all its parts that it tends to move steadily and horizontally, and the acquisition of this adjustment or art of "balancing" in the air is an enormously difficult thing, and which, it will be seen later, took years to acquire.

My first experiments in it, then, were with models like these, but from them I got only a rude idea how to balance the future aërodrome, partly on account of the brevity of their flight, which only lasted a few seconds, partly on account of its irregularity. Although, then, much time and labor were spent by me on these, it was not possible to learn much about the balancing from them.

Thus it appeared that something which could give longer and steadier flights than india rubber must be used as a motor, even for the preliminary trials, and calculations and experiments were made upon the use of compressed air, carbonic-acid gas, electricity in primary and storage batteries, and numerous other contrivances, but all in vain. The gas engine promised to be best ultimately, but nothing save steam gave any promise of immediate success in supporting a machine which would teach these conditions of flight by actual trial, for all were too heavy, weight being the great enemy. It was true also that the steam-driven model could not be properly constructed until the principal conditions of flight were learned, nor these be learned till the working model was experimented with, so that it seemed that the inventor was shut up in a sort of vicious circle.

However, it was necessary to begin in some way, or give up at the outset, and the construction began with a machine to be driven by a steam engine, through the means of propeller wheels, somewhat like the twin screws of a modern steamship, but placed amidships, not at the stern. There were to be rigid and motionless wings, slightly inclined, like the surface of a kite, and a construction was made on this plan which gave, if much disappointment, a good deal of useful experience. It was intended to make a machine that would weigh 20 or 25 pounds, constructed of steel tubes. The engines were made with the best advice to be got (I am not an engineer); but while the boiler was a good deal too heavy, it was still too small to get up steam for the engines, which weighed about 4 pounds, and could have developed a horsepower if there were steam enough. This machine, which was to be moved by two propelling screws, was labored on for many months, with the result that the weight was constantly increased beyond the estimate until, before it was done, the whole weighed over 40 pounds, and yet could only get steam for about a half horsepower, which, after deductions for loss in transmission, would give not more than half that again in actual thrust. It was clear that whatever pains it had cost, it must be abandoned.

This aërodrome could not then have flown; but having learned from it the formidable difficulty of making such a thing light enough, another was constructed, which was made in the other extreme, with two engines to be driven by compressed air, the whole weighing but 5 or 6 pounds. The power proved insufficient. Then came another, with engines to use carbonic-acid gas, which failed from a similar cause. Then followed a small one to be run by steam, which gave some promise of success, but when tried indoors it was found to lift only about one-sixth of its own weight. In each of these the construction of the whole was remodeled to get the greatest strength and lightness combined, but though each was an improvement on its predecessor, it seemed to become more and more doubtful whether it could ever be made sufficiently light, and whether the desired end could be reached at all.

The chief obstacle proved to be not with the engines, which were made surprisingly light after sufficient experiment. The great difficulty was to make a boiler of almost no weight which would give steam enough, and this was a most wearying one. There must be also a certain amount of wing surface, and large wings weighed prohibitively; there must be a frame to hold all together, and the frame, if made strong enough, must yet weigh so little that it seemed impossible to make it. These were the difficulties that I still found myself in after two years of experiment, and it seemed at this stage again as if it must, after all, be given up as a hopeless task, for somehow the thing had to be built stronger and lighter yet.

Now, in all ordinary construction, as in building a steamboat or a house, engineers have what they call a factor of safety. An iron column, for instance, will be made strong enough to hold five or ten times the weight that is ever going to be put upon it, but if we try anything of the kind here the construction will be too heavy to fly. Everything in the work has got to be so light as to be on the edge of breaking down and disaster, and when the breakdown comes all we can do is to find what is the weakest part and make that part stronger; and in this way work went on, week by week and month by month, constantly altering the form of construction so as to strengthen the weakest parts, until, to abridge a story which extended over years, it was finally brought nearly to the shape it is now, where the completed mechanism, furnishing over a horsepower, weighs collectively something less than 7 pounds. This does not include water, the amount of which depends on how long we are to run; but the whole thing, as now constructed, boiler, fire grate, and all that is required to turn out an actual horsepower and more, weighs something less than one one-hundredth part of what the horse himself does. I am here anticipating; but after these first three years something not greatly inferior to this was already reached, and so long ago as that, there had accordingly been secured mechanical power to fly, if that were all—but it is not all.

After that came years more of delay arising from other causes, and I can hardly repeat the long story of subsequent disappointment, which commenced with the first attempts at actual flight.

Mechanical power to fly was, as I say, obtained three years ago; the machine could lift itself if it ran along a railroad track, and it might seem as though, when it could lift itself, the problem was solved. I knew that it was far from solved, but felt that the point was reached where an attempt at actual free flight should be made, though the anticipated difficulties of this were of quite another order than those experienced in shop construction. It is enough to look up at the gulls or buzzards soaring overhead, and to watch the incessant rocking and balancing which accompanies their gliding motion, to apprehend that they find something more than mere strength of wing necessary, and that the machine would have need of something more than mechanical power, though what this something was was not clear. It looked as though it might need a power like instinctive adaptation to the varying needs of each moment, something that even an intelligent steersman on board could hardly supply, but to find what this was a trial had to be made. The first difficulty seemed to be to make the initial flight in such conditions that the machine would not wreck itself at the outset in its descent, and the first question was where to attempt to make the flight.

It became clear, without much thought, that since the machine was at first unprovided with any means to save it from breakage on striking against the ground, it would be well in the initial stage of the experiment not to have it light on the ground at all, but on the water. As it was probable that while skill in launching was being gained, and until after practice had made perfect, failures would occur, and as it was not desired to make any public exhibition of these, a great many places were examined along the shores of the Potomac and on its high bluffs which were condemned partly for their publicity, but partly for another reason. In the course of my experiments I had found out, among the infinite things pertaining to this problem, that the machine must begin to fly in the face of the wind and just in the opposite way to a ship, which begins its voyage with the wind behind it.

If the reader has ever noticed a soaring bird get upon the wing he will see that it does so with the breeze against it, and thus whenever the aërodrome is cast into the air it must face a wind which may happen to blow from the north, south, east, or west, and we had better not make the launching station a place like the bank of a river, where it can go only one way. It was necessary, then, to send it from something which could be turned in any direction, and taking this need in connection with the desirability that at first the airship should light in the water, there came at last the idea (which seems obvious enough when it is stated) of getting some kind of a barge or boat and building a small structure upon it which could house the aërodrome when not in use, and from whose flat roof it could be launched in any direction. Means for this were limited, but a little "scow" was procured, and on it was built a primitive sort of a house, one story high, and on the house a platform about 10 feet higher, so that the top of the platform was about 20 feet from the water, and this was to be the place of the launch (Pl. II). This boat it was found necessary to take down the river as much as 30 miles from Washington, where I then was—since no suitable place could be found nearer—to an island having a stretch of quiet water between it and the main shore; and here the first experiments in attempted flight developed difficulties of a new kind—difficulties which were partly anticipated, but which nobody would probably have conjectured would be of their actually formidable character, which was such as for a long time to prevent any trial being made at all. They arose partly out of the fact that even such a flying machine as a soaring bird has to get up an artificial speed before it is on the wing.

Some soaring birds do this by an initial run upon the ground, and even under the most urgent pressure can not fly without it.

Take the following graphic description of the commencement of an eagle's flight (the writer was in Egypt, and the "sandy soil" was that of the banks of the Nile):

> An approach to within 80 yards aroused the king of birds from his apathy. He partly opened his enormous wings, but stirs not yet from his station. On gaining a few feet more he begins to *walk* away with half-expanded, but motionless, wings. Now for the chance. Fire! A charge of No. 3 from eleven bore rattles audibly but ineffectively upon his densely feathered body; his walk increases to a run, he gathers speed with his slowly waving wings, and eventually leaves the ground. Rising at a gradual inclination, he mounts aloft and sails majestically away to his place of refuge in the Libyan range, distant at least 5 miles from where he rose. Some fragments of feathers denoted the spot where the shot had struck him. The marks of his claws were traceable in the sandy soil, as, at first with firm and decided digs, he forced his way; but as he lightened his body and increased his speed with the aid of his wings, the imprints of his talons gradually merged into long scratches. The measured distance from the point where these vanished to the place where he had stood proved that with all the stimulus that the shot must have given to his exertions he had been compelled to run full 20 yards before he could raise himself from the earth.

We have not all had a chance to see this striking illustration of the necessity of getting up a preliminary speed before soaring, but many of us have disturbed wild ducks on the water and noticed them run along it, flapping their wings for some distance to get velocity before they can fly, and the necessity of the initial velocity is at least as great with our flying machine as it is with a bird.

To get up this preliminary speed many plans were proposed, one of which was to put the aërodrome on the deck of a steamboat, and go faster and faster until the head wind lifted it off the deck. This sounds reasonable, but is absolutely impracticable, for when the aërodrome is set up anywhere in the open air we find that the very slightest wind will turn it over, unless it is firmly held. The whole must be in motion, but in motion from something to which it is held till that critical instant when it is set free as it springs into the air.

The house boat was fitted with an apparatus for launching the aërodrome with a certain initial velocity, and was (in 1893) taken down the river and moored in the stretch of quiet water I have mentioned—the general features of the place being indicated on the accompanying map, page 215—and it was here that the first trials at launching were made, under the difficulties to which I have alluded.

Perhaps the reader will take patience to hear an abstract of a part of the diary of these trials, which commenced with a small aërodrome which had finally been built to weigh only about 10 pounds, which had an engine of not quite one-half horsepower, and which could lift much more than was theoretically necessary to enable it to fly. The exact construction of this early aërodrome is unimportant, as it was replaced later by an improved one, of which a drawing is given on page 213, but it was the first outcome of the series of experiments which had occupied three years, though the disposition of its supporting surfaces, which should cause it to be properly balanced in the air and neither fly up nor down, had yet to be ascertained by trial.

What must still precede this trial was the provision of the apparatus for launching it into the air. It is a difficult thing to launch a ship, although gravity keeps it down upon the ways, but the problem here is that of launching a kind of ship which is as ready to go up into the air like a balloon as to go off sideways, and readier to do either than to go straight forward, as it is wanted to do, for though there is no gas in the flying machine, its great extent of wing surface renders it something like an albatross on a ship's deck—the most unmanageable and helpless of creatures until it is in its proper element.

If there were an absolute calm, which never really happens, it would still be impracticable to launch it as a ship is launched, because the wind made by running it along would get under the wings and turn it over. But there is always more or less wind, and even the gentlest breeze was afterwards found to make the air ship unmanageable unless it was absolutely clamped down to whatever served to launch it, and when it was thus firmly clamped, as it must be at several distinct points, it was necessary that it should be released simultaneously at all these at the one critical instant that it was leaping into the air. This is another difficult condition, but that it is an indispensable one may be inferred from what has been said. In the first form of launching piece this initial velocity was sought to be attained by a spring, which threw forward the supporting frame on which the aërodrome rested; but at this time the extreme susceptibility of the whole construction to injury from the wind and the need of protecting it from even the gentlest breeze had not been appreciated by experience. On November 18, 1893, the aërodrome had been taken down the river, and the whole day was spent in waiting for a calm, as the machine could not be held in position for launching for two seconds in the lightest breeze. The party returned to Washington and came down again on the 20th, and although it seemed that there was scarcely any movement in the air, what little remained was enough to make it impossible to maintain the aërodrome in position. It was let go, notwithstanding, and a portion struck against the edge of the launching piece, and all fell into the water before it had an opportunity to fly.

On the 24th another trip was made and another day spent ineffectively on account of the wind. On the 27th there was a similar experience, and here four days and four (round-trip) journeys of 60 miles each had been spent without a single result. This may seem to be a trial of patience, but it was repeated in December, when five fruitless trips were made, and thus nine such trips were made in these two months and but once was the aërodrome even attempted to be launched, and this attempt was attended with disaster. The principal cause lay, as I have said, in the unrecognized amount of difficulty introduced even by the very smallest wind, as a breeze of 3 or 4 miles an hour, hardly perceptible to the face, was enough to keep the airship from resting in place for the critical seconds preceding the launching.

If we remember that this is all irrespective of the fitness of the launching piece itself, which at first did not get even a chance for trial, some of the difficulties may be better understood; and there were many others.

During most of the year of 1894 there was the same record of defeat. Five more trial trips were made in the spring and summer, during which various forms of launching apparatus were tried with varied forms of disaster. Then it was sought to hold the aërodrome out over the water and let it drop from the greatest attainable height, with the hope that it might acquire the requisite speed of advance before the water was reached. It will hardly be anticipated that it was found impracticable at first to simply let it drop without something going wrong, but so it was, and it soon became evident that even were this not the case a far greater time of fall was requisite for this method than that at command. The result was that in all these eleven months the aërodrome had not been launched, owing to difficulties which seem so slight that one who has not experienced them may wonder at the trouble they caused.

Finally, in October, 1894, an entirely new launching apparatus was completed, which embodied the dozen or more requisites, the need for which had been independently proved in this long process of trial and error. Among these was the primary one that it was capable of sending the aërodrome off at the requisite initial speed, in the face of a wind from whichever quarter it blew, and it had many more facilities which practice had proved indispensable. (Pl. III.)

This new launching piece did its work in this respect effectively, and subsequent disaster was, at any rate, not due to it. But now a new series of failures took place, which could not be attributed to any defect of the launching apparatus, but to a cause which was at first obscure, for sometimes the aërodrome, when successfully launched would dash down forward and into the water, and sometimes (under apparently identically like conditions) would sweep almost vertically upward in the air and fall back, thus behaving in entirely opposite ways, although the circumstances of flight seemed to be the same. The cause of this class of failure was finally found in the fact that as soon as the whole was upborne by the air, the wings yielded under the pressure which supported them, and were momentarily distorted from the form designed and which they appeared to possess. "Momentarily," but enough to cause the wind to catch the top, directing the flight downward, or under them, directing it upward, and to wreck the experiment. When the cause of the difficulty was found, the cure was not easy, for it was necessary to make these great sustaining surfaces rigid so that they could not bend, and to do this without making them heavy, since weight was still the enemy; and nearly a year passed in these experiments.

Has the reader enough of this tale of disaster? If so, he may be spared the account of what went on in the same way. Launch after launch was successively made. The wings were finally, and after infinite patience and labor, made at once light enough and strong enough to do the work, and now in the long struggle the way had been fought up to the face of the final difficulty, in which nearly a year more passed, for the all-important difficulty of balancing the aërodrome was now reached, where it could be discriminated from other preliminary ones, which have been alluded to, and which at first obscured it. If the reader will look at the hawk or any soaring bird, he will see that as it sails through the air without flapping the wing, there are hardly two consecutive seconds of its flight in which it is not swaying a little from side to side, lifting one wing or the other, or turning in a way that suggests an acrobat on a tight rope, only that the bird uses its widely outstretched wings in place of the pole.

There is something, then, which is difficult even for the bird in this act of balancing. In fact, he is sailing so close to the wind in order to fly at all that if he dips his head but the least he will catch the wind on the top of his wing and fall, as I have seen gulls do, when they have literally tumbled toward the water before they could recover themselves.

Besides this, there must be some provision for guarding against the incessant, irregular currents of the wind, for the wind as a whole—and this is a point of prime importance—is not a thing moving along all of a piece, like water in the Gulf Stream. Far from it. The wind, when we come to study it, as we have to do here, is found to be made of innumerable currents and countercurrents, which exist altogether and simultaneously in the gentlest breeze, which is in reality going fifty ways at once, although, as a whole, it may come from the east or the west; and if we could see it, it would be something like seeing the rapids below Niagara, where there is an infinite variety of motion in the parts, although there is a common movement of the stream as a whole.

All this has to be provided for in our mechanical bird, which has neither intelligence nor instinct, without which, although there be all the power of the engines requisite, all the rigidity of wing, all the requisite initial velocity, it still can not fly. This is what is meant by balancing, or the disposal of the parts, so that the air ship will have a position of equilibrium into which it tends to fall when it is disturbed,

PREPARING TO LAUNCH THE AERODROME.

From a photograph by A. Graham Bell, esq.

THE AERODROME IN FLIGHT, MAY 6, 1896.

Two views from instantaneous photographs taken by A. Graham Bell, esq.

and which will enable it to move of its own volition, as it were, in a horizontal course.

Now the reader may be prepared to look at the apparatus which finally has flown. (See diagram.) In the completed form we see two pairs of wings, each slightly curved, each attached to a long steel rod which supports them both, and from which depends the body of the machine, in which are the boilers, the engines, the machinery, and the propeller wheels, these latter being not in the position of those of an ocean steamer, but more nearly amidships. They are made sometimes of wood, sometimes of steel and canvas, and are between 3 and 4 feet in diameter.

The hull itself is formed of steel tubing. The front portion is closed by a sheathing of metal which hides from view the fire grate and apparatus for heating, but allows us to see a little of the coils of the boiler and all of the relatively large smokestack in which it ends. The conical vessel in front is an empty float, whose use is to keep the whole from sinking if it should fall in the water.

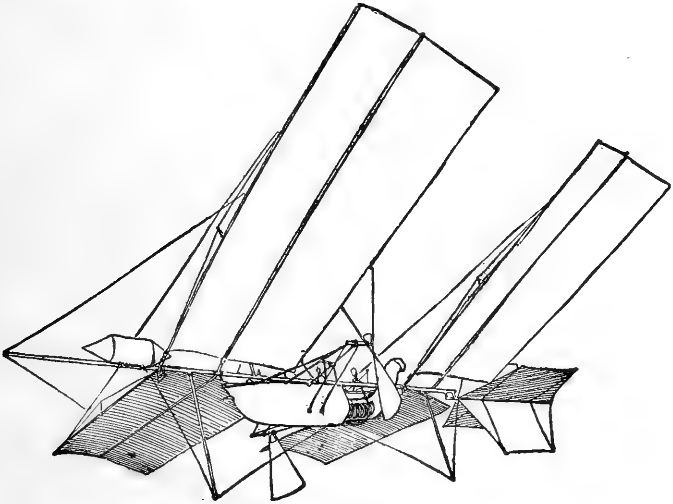


Diagram of the aërodrome.

This boiler supplies steam for an engine of between 1 and 1½ horsepower, and, with its fire grate, weighs a little over 5 pounds. This weight is exclusive of that of the engine, which weighs, with all its moving parts, but 26 ounces. Its duty is to drive the propeller wheels, which it does at rates varying from 800 to 1,200, or even more, turns a minute, the highest number being reached when the whole is speeding freely ahead.

The rudder, it will be noticed, is of a shape very unlike that of a ship, for it is adapted both for vertical and horizontal steering. It is impossible within the limits of such an article as this, however, to give an intelligible account of the manner in which it performs its automatic function. Sufficient it is to say that it does perform it.

The width of the wings from tip to tip is between 12 and 13 feet, and the length of the whole about 16 feet. The weight is nearly thirty pounds, of which about one-fourth is contained in the machinery. The engine and boilers are constructed with an almost single eye to economy of weight, not of force, and are very wasteful of steam, of which they spend their own weight in five minutes. This steam might all be recondensed and the water re-used by proper condensing apparatus, but this can not be easily introduced in so small a scale of construction. With it the time of flight might be hours instead of minutes, but without it the flight (of the present aërodrome) is limited to about five minutes, though in that time, as will be seen presently, it can go some miles; but owing to the danger of its leaving the surface of the water for that of the land, and wrecking itself on shore, the time of flight is limited designedly to less than two minutes.

I have spared the reader an account of numberless delays, from continuous accidents and from failures in attempted flights, which prevented a single entirely satisfactory one during nearly three years after a machine with power to fly had been attained. It is true that the aërodrome maintained itself in the air at many times, but some disaster had so often intervened to prevent a complete flight that the most persistent hope must at some time have yielded. On the 6th of May of last year I had journeyed, perhaps for the twentieth time, to the distant river station and recommenced the weary routine of another launch, with very moderate expectation indeed; and when on that, to me, memorable afternoon the signal was given and the aërodrome sprang into the air[1] I watched it from the shore with hardly a hope that the long series of accidents had come to a close. And yet it had, and for the first time the aërodrome swept continuously through the air like a living thing, and as second after second passed on the face of the stop watch until a minute had gone by and it still flew on, and as I heard the cheering of the few spectators, I felt that something had been accomplished at last, for never in any part of the world or in any period had any machine of man's construction sustained itself in the air before for even half of this brief time. Still the aërodrome went on in a rising course until, at the end of a minute and a half (for which time only it was provided with fuel and water), it had accomplished a little over half a mile, and now it settled rather than fell into the river with a gentle descent. It was immediately taken out and flown again with equal success, nor was there anything to indicate that it might not have flown indefinitely except for the limit put upon it.

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[1] The illustration from an instantaneous photograph by Mr. Bell, shows the machine after Mr. Reed, who was in charge of the launch (and to whom a great deal of the construction of the aërodrome is due), has released it, and when it is in the first instant of its aërial journey. (Pl. III.)

I was accompanied by my friend, Mr. Alexander Graham Bell, who not only witnessed the flight, but took the instantaneous photograph of it which has been given. He spoke of it in a communication to the Institute of France [and in a similar communication to Nature, given in full on page 199]. * * *

On November 28 I obtained, with another aerodrome of somewhat similar construction, a rather longer flight, in which it traversed about three-quarters of a mile, and descended with equal safety. In this the speed was greater, or about 30 miles an hour. The course of this date is indicated by the dotted line in the diagram. We may live to see airships a common sight, but habit has not dulled the edge of wonder, and I wish that the reader could have witnessed the actual spectacle. "It looked like a miracle," said one who saw it, and the photograph, though taken from the original, conveys but imperfectly the impression given by the flight itself.

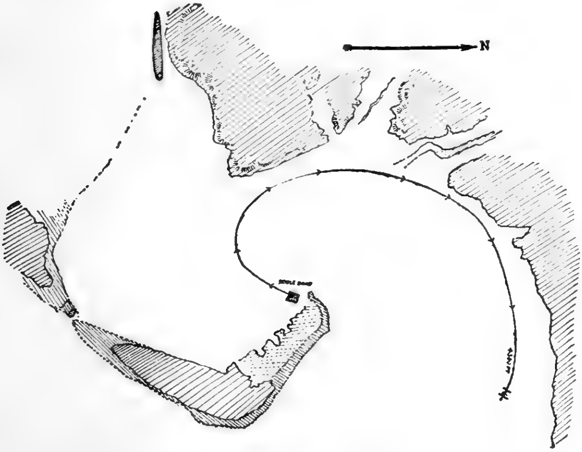
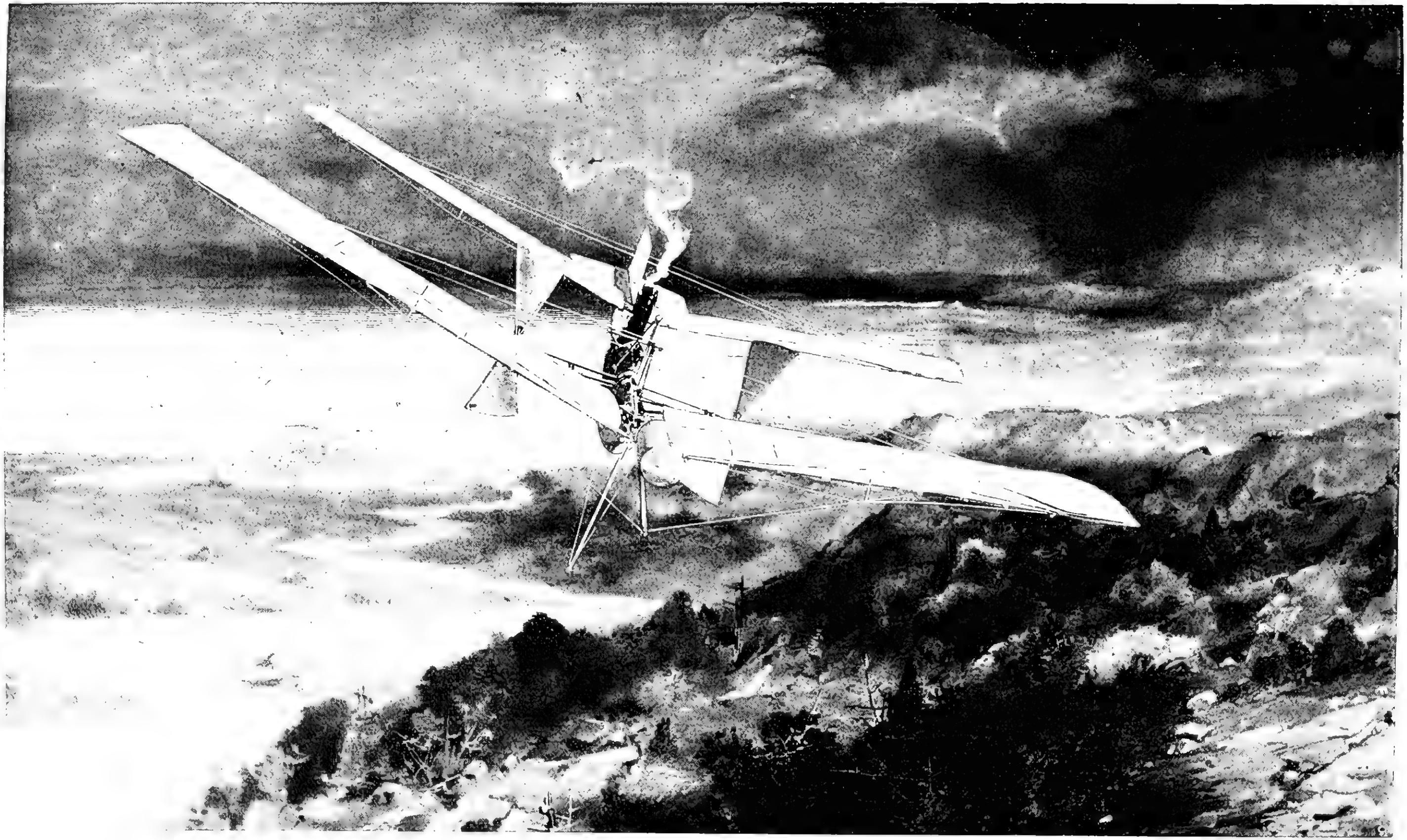


Diagram showing the course of the aërodrome in its flight on the Potomac River at Quantico.

And now, it may be asked, what has been done? This has been done: A "flying machine," so long a type for ridicule, has really flown; it has demonstrated its practicability in the only satisfactory way—by actually flying—and by doing this again and again under conditions which leave no doubt.

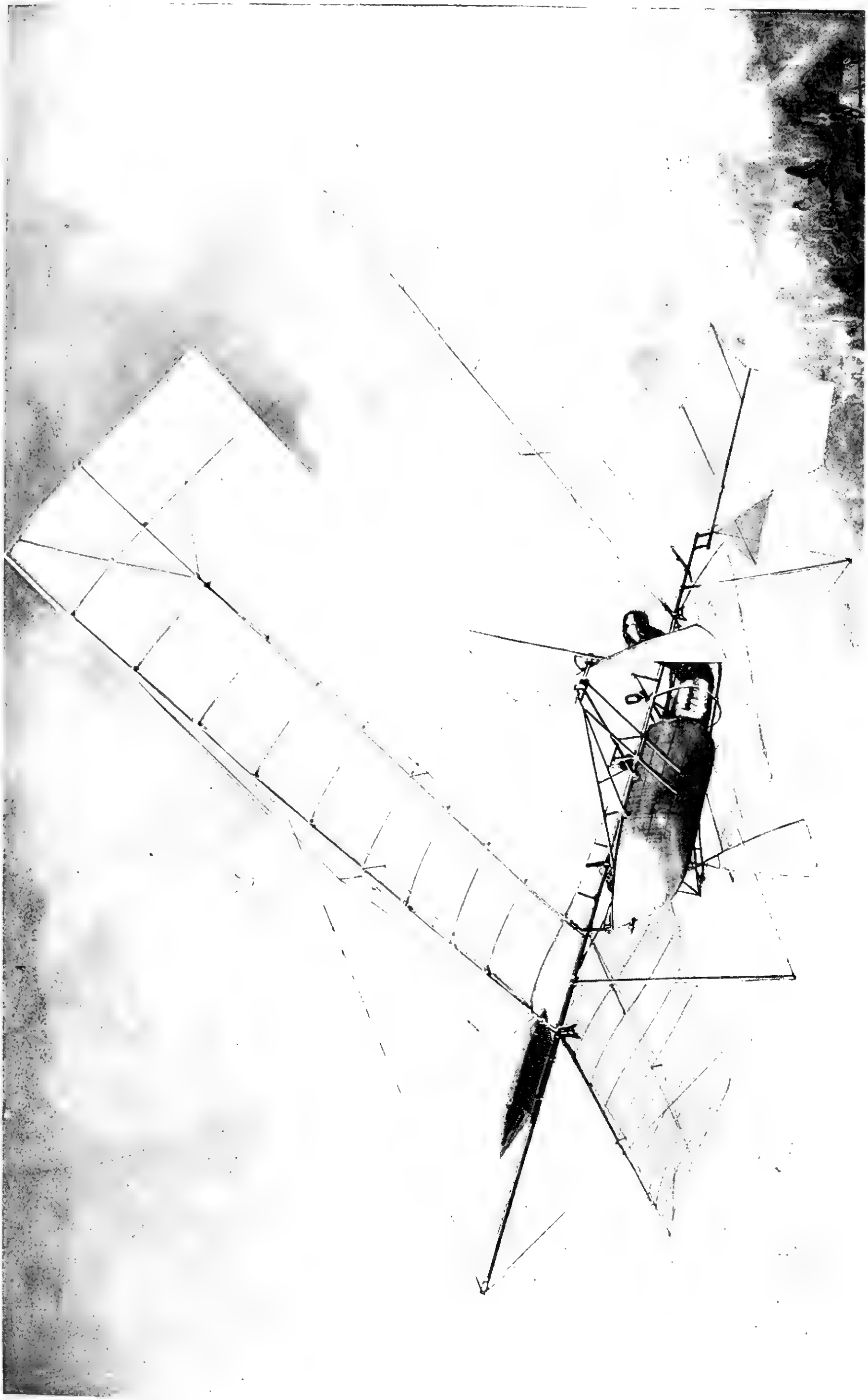
There is no room here to enter on the consideration of the construction of larger machines, or to offer the reasons for believing that they may be built to remain for days in the air, or to travel at speeds higher than any with which we are familiar. Neither is there room to enter on a consideration of their commercial value, or of those applications which will probably first come in the arts of war rather than those of peace; but we may at least see that these may be such as to change the whole conditions of warfare, when each of two opposing hosts will have its every movement known to the other, when no lines of fortification will keep out the foe, and when the difficulties of defending a country against an attacking enemy in the air will be such that we may hope that this will hasten rather than retard the coming of the day when war shall cease.

I have thus far had only a purely scientific interest in the results of these labors. Perhaps if it could have been foreseen at the outset how much labor there was to be, how much of life would be given to it, and how much care, I might have hesitated to enter upon it at all. And now reward must be looked for, if reward there be, in the knowledge that I have done the best I could in a difficult task, with results which it may be hoped will be useful to others. I have brought to a close the portion of the work which seemed to be specially mine—the demonstration of the practicability of mechanical flight—and for the next stage, which is the commercial and practical development of the idea, it is probable that the world may look to others. The world, indeed, will be supine if it do not realize that a new possibility has come to it, and that the great universal highway overhead is now soon to be opened.



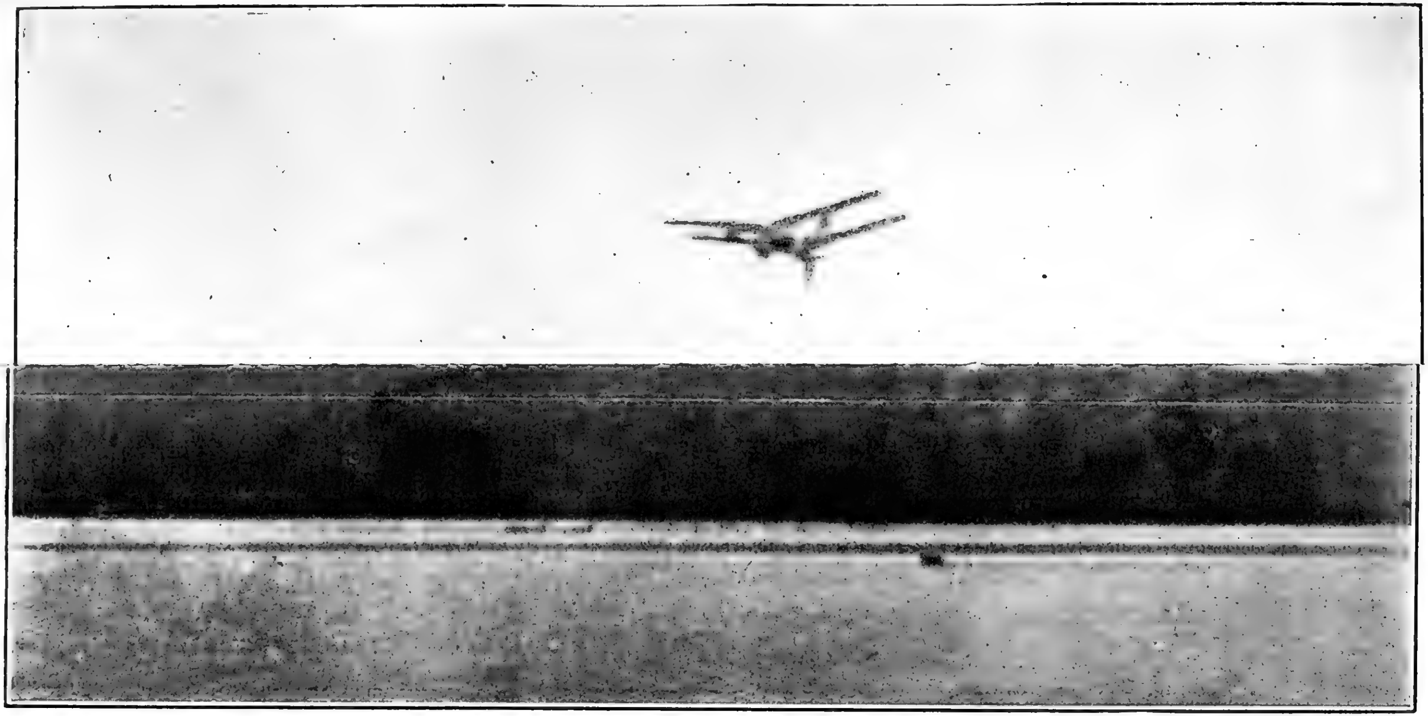
MR. LANGLEY'S AERODROME IN FLIGHT.

A view from above.



THE AERODROME IN FLIGHT.

A view from below.



LANGLEY'S AERODROME NO. 5, IN FLIGHT MAY 6, 1896.

From instantaneous photograph by A. Graham Bell, esq.

PLATE VI.

LANGLEY'S AERODROME NO 5, IN FLIGHT MAY 6, 1896.

From instantaneous photograph by A. Graham Bell, esq

THE ZEPPELIN AIR SHIP.[1]

By Thomas E. Curtis.

(Photos. by Alfred Wolf, Constanz. These are the only photographs authorized by Count Zeppelin.)

With all these experiments going on we ought soon to be able to travel through the air. The celebrated flying machine invented by Professor Langley a few years ago proved that flying machines could fly; and the more recent experiments by Schwarz and Danilewsky have increased the belief that the era of aerial flight was near. The latest experiment, made only a month or two ago, by Count Zeppelin, on Lake Constance, with one of the most ingenious, expensive, and carefully constructed balloons of modern times, was so successful in proving the rigidity and safety of an air ship at a high altitude that the complete submission of the air to the mechanism of man seems nearer than ever at hand. The interest of the whole scientific world in the experiment was deep, and an unwonted exhibition of interest by the ordinary public took place.

The balloon was constructed in a wooden shed on Lake Constance, at a little town called Manzell, near Friedrichshafen, and this curious pointed structure, with twenty-two big windows (eleven on each side) and its almost innumerable pontoons (on which the huge building floated), has for many months been an object of great attraction to those visiting the beautiful Swiss lake.

The illustration with which we open this article, while it does not show the pointed end, so constructed to diminish the resistance of the air, gives an admirable idea of the balloon-house. Four hundred and fifty feet long, 78 broad, and 66 high, it is indeed a formidable object. The rear end, through which we are able to see part of the air ship, is usually covered with a curtain, to ward off the curious; and the front end is given up to offices, storerooms, and sleeping accommodation for such workmen as have to act as sentinels at night.

There can be little doubt that this construction shed is one of the most perfect of its kind ever devised, and, incidentally, it shows the care and skill with which Count Zeppelin and his engineers prepared

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[1] Reprinted by permission from the Strand Magazine, September, 1900.

themselves against untoward delay and accident in the consummation of their great plan. If, for instance, we could row up to this immense floating structure we should find it resting gracefully on ninety-five pontoons, and we could understand the advantage which such a shed, floating on the bosom of an open lake, would have for the inventor in the experimental trials of his machine. No ground to fall upon, and nothing to run against! Again, by anchoring his shed at one point only the inventor allows it to turn, as on a pivot, with the wind, and thus gains the aid of the wind in getting his ballon out of the shed with the minimum of damage and the maximum of speed.

The cost of the construction of the building in which the balloon was housed alone exceeded 200,000 marks. The plans of the workshop were made by Herr Tafel, a well-known Stuttgart architect, and the construction of the balloon was intrustsd to Herr Kaubler. The construction was carried out by seventy carpenters and thirty mechanics, and that the work was done well and carefully is shown by the fact that every separate piece of material used in the air ship had been tested at least twice.

A word or two more about the shed and we may leave it, with the balloon. If we examine closely we discover that part only of the pontoons support the shed, and that the remainder support the balloon. In other words, the balloon, on its own supports, can be easily moved in and out of the shed. The exit, taking place, for reasons already given, in the direction of the wind, and assisted by it, is particularly safe, as the danger of pressure in the balloon against the sides of a shed—so common in sheds built on land—is avoided. It is reasonably certain that all experiments in air-ship construction will in future take place on water, owing to the success and ease with which the Zeppelin balloon has been taken in and out of its house on Lake Constance.

When the balloon is ready for an ascent it is pulled out of the shed on its own pontoons; and when its flight is over it is placed on the pontoon floor and drawn into the shed. Each operation takes but a few minutes. Our second illustration and several succeeding illustrations gives an excellent idea of the floor upon which the balloon rests before flight. It also affords us our first real view of the huge cigar-like structure that has so frequently flown itself into world-wide fame. Conical at both ends, in order that resistance to the air may be lessened, and cylindrical in shape, it measures 390 feet in length, and has a diameter of about 39 feet. It looks, even at a close view, like a single balloon, but in reality it consists of seventeen small balloons, because it is divided into seventeen sections, each gastight, like the water-tight compartments on board a steamship. The interior is a massive framework of aluminum rods, stretching from one end of the balloon to the other and held in place by seventeen polygonal rings arranged 24 feet apart. Each ring is supported by aluminum wires, and the whole interior, looked at from one end, appears as if a lot of bicycle wheels had been placed side by side. The whole series of seventeen sections is covered with a tough and light network of ramie.

Each section, as we have said, is a balloon in itself, and each section is covered with a light silk texture, which by virtue of an india-rubber coating is, in the general sense of the word, gastight. So tight, indeed, has each balloon been made that one filling of hydrogen (the lightest and most volatile of gases) has been proved to last for two or three weeks.

The exterior of the balloon is made of pegamoid, which protects it both from sun and rain. The total capacity of the interior balloons is about 12,000 cubic yards of hydrogen gas; and, lest any of our readers should bankrupt himself by attempting to construct a Zeppelin balloon, we may as well add that each filling costs in the neighborhood of £500. When the balloon is ready to be filled the hydrogen gas, in 2,200 iron bottles, is brought alongside the balloon shed on pontoons, each containing 130 bottles and all connected with each other, thus forming a single reservoir, which in turn is connected with the balloon by a distributing pipe. It takes five hours to fill the whole balloon.

It is one thing to build a balloon and another thing to make it go. It is still another thing to be able to control its flight, steering it this way and that, with the wind and against it. Hundreds of inventors, including the lamented Darius Green, have failed because of their methods of steering and propulsion, or the absence of each. But it is in these very respects that Count Zeppelin may well be said to have been successful. More, however, of that anon. Suffice to say here that the propulsion of the great balloon under consideration is effected by four screws made of aluminum, all working as do the propellers of a ship. Two of these screws are situated about a third of the total length from the bow, and the other two a like distance from the stern. Each screw makes over a thousand revolutions a minute.

In several of our illustrations the cars of the balloon are plainly shown. These also are made of aluminum—indeed every part of the air ship is made of the lightest possible material—and are attached to the inner framework by rods and wires. The cars are about 5 feet broad and 3 feet deep and are situated each under a pair of screws, which may be noted projecting from the sides of the balloon. The cars carry the motors for driving the propellers, and benzine, by virtue of not requiring such heavy machinery to use it with, has been chosen for the motive power. Enough benzine may be carried to work the balloon for ten successive hours. It may be added that the cars of the balloon are connected, as shown in our photographs, by a narrow passageway, made of aluminum wires and plates, which are firmly connected with the balloon above.

One very noteworthy feature of this latest air ship is the sliding weight—made of lead and weighing 300 kilos—by means of which the balloon is raised or lowered at the bow or stern. In our illustrations of this article, particularly the last picture, we may observe the balloon at a decided angle in the sky. This shows the work of the sliding weight. It was secured in the center of the dragging-cable, the ends of which were fastened fore and aft. As the dragging cable was about 328 feet long, with a slack of about 75½ feet, the stability of the vessel was greatly improved. The heavy, deep-hanging weight acted as a regulator of the pendulum-like motion of the air ship. In order to provide for a descent into the water the sliding weight is inclosed in a water-tight box filled with air, which causes the box to float when it touches the water. The value of this piece of mechanism was proved, as is hereafter shown, when the first experiment in flight was made, although an unfortunate accident occurred to it, which brought the flight to an abrupt conclusion.

One word more and we are done with the technical construction of the balloon. The steering apparatus consists of rudders placed at the bow and stern of the balloon, and controlled by wires attached to the two cars. Each rudder is made of cloth with a framework of aluminum.

The Government lent its aid in a manner worthy of emulation by governments which are less up to date. When, for instance, the inventor discovered that by allowing his building to float freely about on the lake he was hampering himself with considerable difficulties, the naval dockyards at Kiel came to his support with the loan of four gigantic anchors, by which the floating workshop could be fastened. The Kaiser was interested in the air ship throughout its construction, and only the inventor and his immediate colleagues will ever know how much the imperial aid and interest stimulated them in their endeavors.

The 30th of June last witnessed a tremendous gathering of scientific men and others on the shores of Lake Constance, who had come from far and wide to attend the experimental trials of the Zeppelin balloon. Experts from various countries were present, and the Kaiser, always keenly interested in the problems of aëronauters, was represented by several Germans of wide experience. It was a day when the fate of an old man of 70 was to be decided—a man who, with exceeding enthusiasm in his hobby, had put £20,000 into the construction of a flying machine that had not yet taken its first flight into the air.

The Balloon Company, which had been formed with a capital of £40,000, half of which was contributed by Count Zeppelin, chartered a steamer on that day and carried the experts to the scene of the trials. A delay in filling the balloon occurred and the trial was postponed. The following day the trial was delayed by a stiff wind, but in the evening the balloon was drawn from the shed, ballasted and balanced, and was sent up a few feet into the air in order that its propelling power might be tested. Night then intervened, and the real trial was again postponed.

The next day, July 2, proclaimed the success of the aërial monster over which so many months of mental and mechanical labor had been spent. There was a touch of romance about it too, for it was not until sundown that the trial trip began, and it was then that the gray-headed inventor, courageous and confident of the success of his plans, ventured on a voyage in an untried ship into the darkening night. A light wind prevailed. Punctually at half past 7 the balloon was taken from the shed, and, held in position by several ropes, was allowed to rise about 75 feet. At 8 o'clock it was released, and with Count Zeppelin, and four assistants in the two cars, began slowly to ascend.

Zeppelin himself, as we have said, is a man of 70, who for many years has devoted his whole time and energy to the study of aërial navigation. It has been said that the Schwarz balloon, which was described in this magazine in March, 1898, gave him the idea of the present air ship; and those who have read that article will note many points of similarity in the two pieces of mechanism. Schwarz died prematurely, and his idea had to be carried to fruition by his friends. The balloon, for this reason, was, as time proved, a failure; but Count Zeppelin, noting the great ingenuity of its construction, decided to improve it, upon the lines of its lamented inventor. The Count lives in the fine castle of Ebersberg, near Constance, and he looks back on a distinguished career in the Franco-German war. He made an extremely daring ride at one time through the outposts of the enemy, and it is said that the desirability of having some quicker and safer means of scouting than that in use appealed to him strongly, and suggested at once an aërial machine. He consulted and took the advice of various authorities in aërial navigation, both of his own country and abroad, and finally succeeeed in floating, at Stuttgart, the company already mentioned, which has so successfully built the balloon.

The best account of the short and exciting trip of the Zeppelin balloon has been given by Captain-Lieutenant D. von Bethge, steamship inspector of Friedrichshafen, who may briefly be quoted: "It was an exciting moment," he writes, "when the first command to let go the cables sounded from the raft, and the air ship, which, up till then, had been held by the hands of the firemen, laborers, and soldiers, rose slowly into the air, and suddenly, at the height of 25 meters (82 feet) was released and soared upward. At first the vessel descended somewhat before the light easterly breeze which was blowing; but when the engines began to work it steamed against the wind, then turned to right and left, and afterwards traveled with the wind, turning occasionally hither and thither until it reached Immenstaad." The distance traveled was about 3¼ miles.

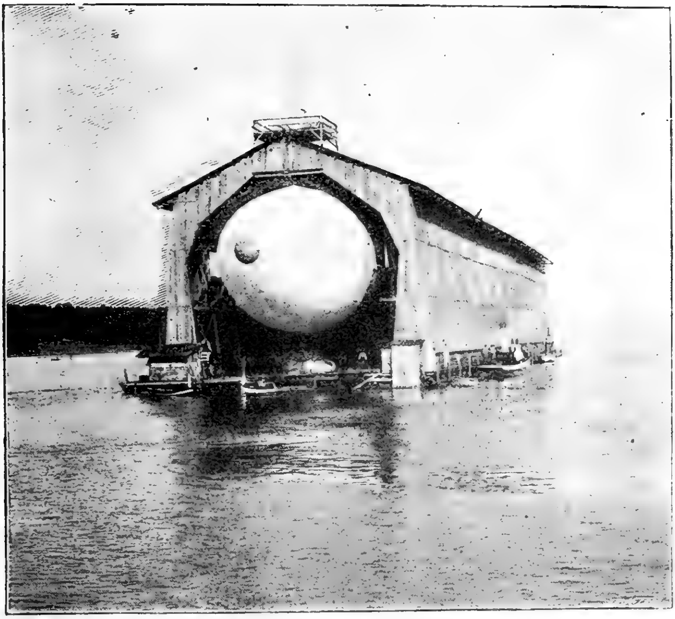
In the early part of the trip an accident to the steering mechanism occurred. A winch broke and hindered the further use of the running weight, which, as has already been mentioned, was provided in order that the bow or stern might be lowered or raised, and the horizontal position regained. Notwithstanding the accident, Lieutenant Bethge goes on to say, "It was still possible to turn the balloon to the left against the wind, but as it was impossible, owing to the broken cable, to turn to the right, Count Zeppelin decided to descend." The descent took place seventeen minutes after the ascent.

Count Zeppelin has written an account of the trial trip which is of special interest, as it comes from one with a full knowledge of all the details. "The task," he says, "of bringing down the air ship took place without a hitch. In spite of a rapid and considerable escape of gas, followed by but a small sacrifice of ballast, the descent took place so gently that a descent onto hard ground would seem devoid of danger."

The accident to the running weight made it necessary to avert the imminent danger of capsizing by stopping and going astern with the screws. "Henceforth," he adds, "the whole voyage consisted of alternately going ahead, and then astern, with the screws, so as to prevent excessive inclination. A further reason for this alternate motion arose from the circumstance that the air ship, which at first obeyed her helm well to starboard, ran more and more to the left, owing, apparently, to a curve to larboard, due to the drag of the running weight. For this reason also, in order to avoid being driven on over the land, it was necessary to go astern with the screws whenever the stern pointed toward the lake."

It seems from all accounts that the floating capacity and the great lateral stability of the Zeppelin air ship have been conclusively proved. The ship floated smoothly in a horizontal position. It also obeyed its rudder up to the moment when the steering cable broke. Moreover, as Count Zeppelin himself says, "It has been proved that there is no danger of fire in connection with the use of the air ship in ordinary conditions."

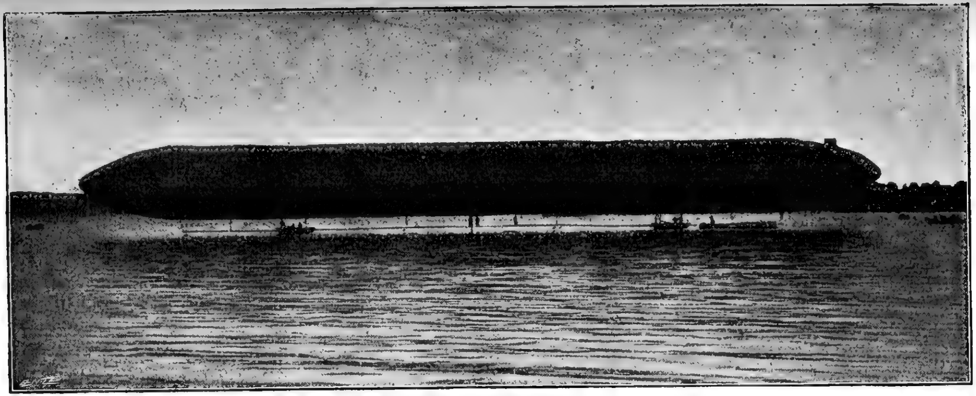
The rigidity of the balloon—important in view of its great length—has also been established. It is unfortunate that no exact statement of speed was obtainable owing to the accident, although the reports of several experts stationed at different points, now, at the moment of writing, being made out, may give an approximate idea of that speed. Bethge estimates that the rapidity of flight before the wind toward Immenstaad was about 9 meters (29 feet) per second, from which figure the trifling wind velocity has to be deducted. It is enough, however, to say that a dirigible balloon, which can maintain a state of equilibrium and descend with perfect safety to its passengers, has become an established fact. Future experiments, which the fortune and enthusiasm of Count Zeppelin will enable him to carry out, will doubtless bring the Zeppelin balloon to a gratifying perfection.



ZEPPELIN AIR SHIP IN FLOATING HOUSE ON LAKE CONSTANCE, SHOWING THE REAR END, CONICAL-SHAPE.

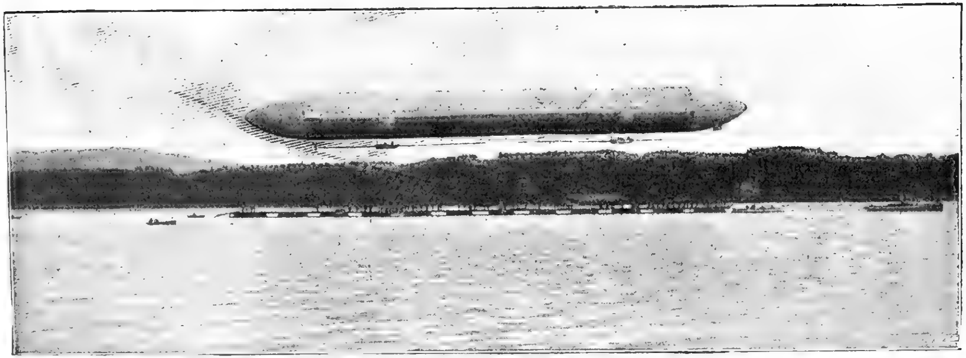
ZEPPELIN AIR SHIP FLOATING ON PONTOONS AFTER HAVING BEEN DRAWN FROM SHED.

THE AIR SHIP BEING TOWED UPON THE LAKE.



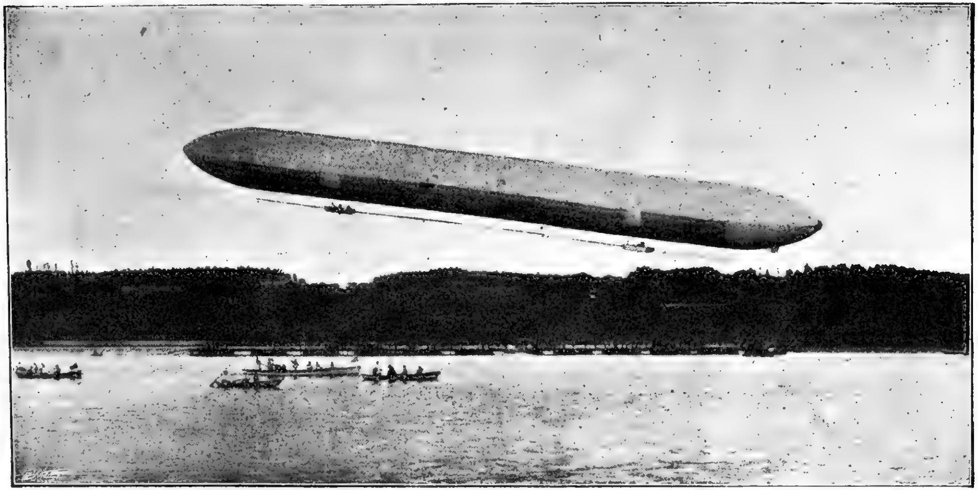
The Air Ship ready for Ascent.

Photograph shows cars of balloon in which motors and passengers are carried.



The Air Ship ready for Flight.

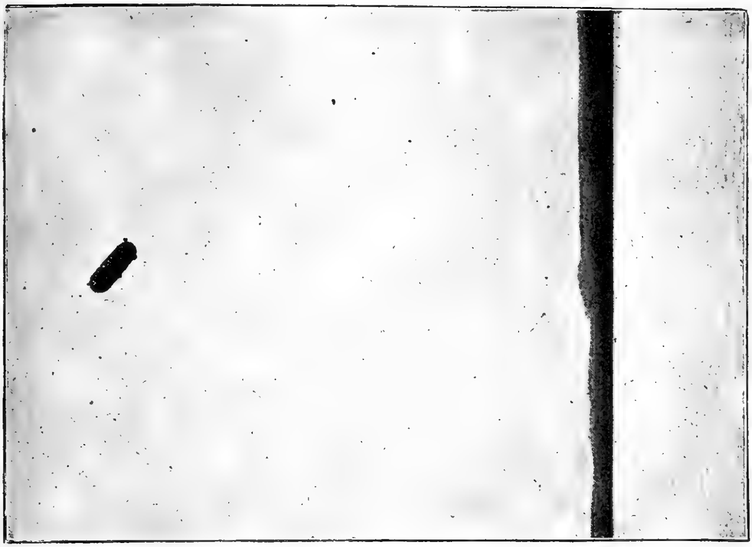
Held above pontoons for few minutes before signal to let go.



THE AIR SHIP IN FULL FLIGHT.

By comparing this illustration with the next one it will be seen how operation of sliding weight tilted balloon without destroying equilibrium.

ANOTHER VIEW OF THE AIR SHIP IN FULL FLIGHT.



THE AIR SHIP SLOWLY DESCENDING, AFTER ACCIDENT, TO BOSOM OF LAKE, ON WHICH IT LIGHTED WITHOUT DANGER TO OCCUPANTS.

THE AIR SHIP AT A HIGH ALTITUDE.

THE USE OF KITES TO OBTAIN METEOROLOGICAL OBSERVATIONS.[1]

By A. Lawrence Rotch,

Director of Blue Hill Meteorological Observatory.

Historical researches, stimulated by the recent practical applications of kites, seem to show that their first use for scientific purposes was in 1749, when Dr. Alexander Wilson, of Glasgow, and his pupil, Thomas Melvill, lifted thermometers attached to kites into the clouds. These kites, from 4 to 7 feet high and covered with paper, were fastened one behind the other, each kite taking up as much line as could be supported, thereby allowing its companion to soar to an elevation proportionally higher. It is related that "the uppermost one ascended to an amazing height, disappearing at times among the white summer clouds, while all the rest, in a series, formed with it in the air below such a lofty scale, and that, too, affected by such regular and conspiring motions as at once changed a boyish pastime into a spectacle which greatly interested every beholder. * * * To obtain the information they wanted, they contrived that thermometers, properly secured and having bushy tassels of paper tied to them, should be let fall at stated periods from some of the higher kites, which was accomplished by the gradual singeing of a match line." Since the minimum thermometer had not then been invented it is difficult to understand how the thermometers were prevented from changing their readings while falling to the ground. The account concludes: "When engaged in these experiments, though now and then they communicated immediately with the clouds, yet, as this happened always in fine weather, no symptoms whatever of an electrical nature came under their observation. The sublime analysis of the thunderbolt and of the electricity of the atmosphere lay yet entirely undiscovered, and was reserved two years longer for the sagacity of the celebrated Dr. Franklin." Hence it seems that Franklin's famous experiment of collecting the electricity of a thundercloud by means of a kite, performed at Philadelphia in 1752, was not the first scientific application of the kite, and therefore

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[1] Reprinted (with author's revision) from Technology Quarterly and Proceedings of the Society of Arts, Boston, June, 1900.

America can claim only the later and most remarkable development of this means of exploring the air. About 1837 there existed in Philadelphia an organization called the Franklin Kite Club, that flew kites for recreation. Espy, the eminent meteorologist, was a member, and he states "that on those days when columnar clouds form rapidly and numerously the kite was frequently carried upward nearly perpendicularly by columns of ascending air," a phenomenon which is often observed to-day. Espy calculated the height at which clouds should form by the cooling of the air to its dew point, and then employed kites to verify his calculations of the heights of the clouds. Both these methods are utilized in the measurements of cloud heights at Blue Hill.

Kites were employed to get temperatures a hundred feet or more above the Arctic Ocean early in the present century, and in 1847 Mr. W. R. Birt, at the Kew Observatory in England, flew a kite for the purpose of measuring temperature, humidity, wind velocity, etc. His kite, of hexagonal shape, required three strings attached to the ground to keep it steady, and while he proposed to hoist the instruments up to the kite by means of a pulley, it does not appear that this was done or that any observations were obtained. In 1882 Mr. Douglas Archibald in England revived the use of kites for meteorological observations and outlined a comprehensive scheme of exploring the air with kites, which included almost all that has been done since. His actual work, performed during the next three years, was limited to ascertaining the increase of wind velocity with height up to 1,200 feet, and to do this he attached registering anemometers at four different points on the kite wire, but since the total wind movements only were registered from the time the anemometers left the ground until they returned, it was impossible to obtain simultaneous records near the ground and at the kite, as is done to-day. Mr. Archibald in 1887 took the first photograph from a kite, a method which MM. Batut and Wenz developed in France, and Messrs. Eddy and Woglom in the United States.

The subsequent progress of kite flying for meteorological purposes was in this country, and it may be chronologically stated as follows: In 1885 Mr. Alexander McAdie (now of the United States Weather Bureau) repeated Franklin's kite experiment on Blue Hill, with the addition of an electrometer; in 1891 and 1892 he measured simultaneously the electric potential at the base of Blue Hill, on the hill, and with kites as collectors several hundred feet above the hilltop, about the same time that Dr. Weber, in Breslau, Germany, was making a more extensive use of kites for the same purpose. It was no doubt William A. Eddy, of Bayonne, N. J., who turned the attention of American scientific men to kite flying, and created the widespread interest in kites which exists to-day. About 1890, Mr. Eddy lifted thermometers with an ordinary kite, but soon afterwards devised a tailless kite resembling the one used in Java, except that the horizontal crosspiece is nearer the top of the vertical stick, and its ends are bent backward in a bow and connected by a cord. The next year, with several of these kites flown tandem, he lifted a minimum thermometer and proposed to obtain in this way data to forecast the weather.

Up to this time it does not appear that self-recording instruments—that is to say, those which make continuous graphic records—had been raised by kites. In the days of the early experimenters such instruments were too heavy and cumbersome to be lifted by the more or less unmanageable kites, but within the past few years M. Richard, of Paris, has made recording instruments sufficiently simple and light to be attached to kites. In this way it is possible to obtain simultaneous records at the kite and at a station on the ground, and from them to study the differences of temperature and humidity, and this seems to have been done first at Blue Hill Observatory. In August, 1894, Mr. Eddy brought his kites to Blue Hill, and with them lifted a Richard thermograph which had been partly reconstructed of aluminum by Mr. Fergusson, of the observatory, so that it weighed but 2¼ pounds, to the height of 1,400 feet, and here the earliest automatic record of temperature was obtained by a kite. During the next summer Mr. Eddy secured photographs of the observatory and hill by a camera carried between his kites to the height of a hundred feet or more. Now, that the possibility of lifting self-recording meteorological instruments to considerable heights had been demonstrated, an investigation of the thermal and hygrometric conditions of the free air was undertaken by the staff of the Blue Hill Observatory, who had already made an investigation of the currents of air at various heights by measurements of the clouds.

In the early experiments the Eddy, or Malay kites, as they are also called, covered with paper or with varnished cloth and coupled tandem to secure greater safety and lifting power, were used. The kites were attached at several points on the line, for although it can be demonstrated theoretically that a greater height is possible by concentrating all the pull at the end of the line, yet in the actual case of a line which is not infinitely strong the best results are got by distributing the pull, and in this way, too, kites can be added as the wind conditions aloft permit. The Eddy kite flew at a high angle above the horizon and through a considerable range of wind velocity, but it could not be kept permanently in balance or made to adjust itself to great variations in wind velocity, and therefore it was discarded.

The first meteorograph, being a combined recording thermometer and barometer (from which the height can be obtained), was constructed by Mr. Fergusson in August, 1895, and three months later he joined a recording anemometer to the thermometer, which was probably the first apparatus of this kind to be attached to kites. Subsequently there was used the meteorograph, recording atmospheric pressure, air temperature, and relative humidity, designed by M. Richard, of Paris, for use in balloons, but now for the first time made of aluminum. In August, 1895, in addition to the Eddy kites, there was tried the cellular, or box kite, invented by Lawrence Hargrave, of Sydney, Australia, which bears no resemblance to the conventional forms of kites, but consists of two light boxes without tops or bottoms, fastened some distance above each other. The wind exerts its lifting force chiefly upon the front and rear sides of the upper box, the lower box, which inclines to the rear and so receives less pressure preserving the balance, while the ends of the boxes being in line with the wind keep the kite steady, and serve the purpose of the dihedral angle in the Malay kite.

On account of the weight of the large cord necessary to control these kites and the surface which it presented to the wind, a height of 2,000 feet above Blue Hill could not be reached; so, during the winter of 1895–96, following Archibald's example and the methods of deep-sea sounding employed by Captain Sigsbee, United States Navy, steel pianoforte wire was substituted for the cord. This wire is less than half as heavy and less than one-fourth the size of cord having the same strength; and, moreover, its surface is polished, which reduces the friction of the wind blowing past it. With the wire the height of a mile was reached in July, and a mile and two-thirds in October, 1896. Up to this time a reel turned by two men sufficed to draw down the kites, but the increasing pull and length of wire made recourse to steam power necessary. In January, 1897, a grant of money was allotted from the Hodgkins fund of the Smithsonian Institution for the purpose of obtaining meteorological records at heights exceeding 10,000 feet, and no doubt the first application of steam to kiteflying was the winch built by Mr. Fergusson, with ingenious devices for distributing, oiling, and measuring the length of wire. The cumulative pressure of the successive coils of wire finally crushed the drum, and the next apparatus applied the principle of Sir William Thomson's deep-sea sounding apparatus, in which there is no accumulation of pressure. In October, 1897, records were brought down from 11,000 feet, or 1,000 feet above the prescribed height. The kite reel, in its various stages of development, is shown in fig. 1, Plate I.

The kites and apparatus at present employed at Blue Hill will now be described:

The kites are mostly of Hargrave's construction with two rectangular cells covered with cloth or silk, except at their tops and bottoms, and one is secured above the other by four or more sticks. The wooden frames are as light as possible, but are made rigid by guys of steel wire which bind them in all directions. The average weight is about 2 ounces a square foot of lifting surface, which is about the same weight a square foot as the Eddy kites, when all the surface is included in the estimate. The largest of the Hargrave kites stands 9 feet high, weighs 11 pounds, and contains 90 square feet of lifting surface, which in the recent kites is arched, resembling the curvature of a bird's wings (fig. 2, Pl. I). These curved surfaces increase the lift, or upward pull, more than the drift, or motion to leeward, and so the angular elevation is augmented without materially adding to the total pull on the wire, which should not exceed one-half its breaking strength. Another efficient form that has been used at Blue Hill is the "aero-curve kite," made by Mr. C. H. Lamson, of Portland, Me., and shown in fig. 3, (Pl. II). In flight it resembles a soaring bird, and when not in use it can be taken apart and folded up. Mr. Lamson has recently constructed a similar kite, with three superposed surfaces, that has been the leader in some of the highest flights.

A most important factor in the success of the Blue Hill work was the application by Mr. Clayton, of the observatory, to every kite of an elastic cord inserted in the lower part of the bridle to which the flying line is attached; when the wind pressure increases, this stretches and causes the kite to diminish its angle of incidence to the wind until the gust subsides. A kite can be set to pull only a fixed amount in the strongest wind, when the kite will fly nearly horizontal. We are therefore able to calculate the greatest pull that can be exerted on the wire by all the kites, and with this device the kites have flown through gales of 50 or 60 miles an hour without breaking loose or injuring themselves. In general, the angle of the flying lines of the Blue Hill kites is 50° or 60° above the horizon, and in winds of 20 miles an hour the pull on the line is about 1 pound for each square foot of lifting surface in the kite. Kites can be raised in a wind that blows more than 12 miles an hour at the ground, and as the average velocity of the wind for the year on Blue Hill is 18 miles an hour, there are few days when kites can not be flown. In order to fly in the feeblest winds possible a small and light pilot kite has been used to help lift the large and heavier kite into the stronger and steadier wind that usually prevails a short distance above the ground.

The wire to which the kites are attached is steel music wire, 0.032 inch in diameter, weighing 15 pounds a mile, and capable of withstanding a pull of 300 pounds. The wire is spliced in lengths of more than a mile with the greatest care, special pains being taken that no sharp bends or rust spots occur which would cause it to break. To lift the increasing weight of wire, kites are attached at intervals of a few thousand feet by screwing on the wire aluminum clamps to which the kite lines are fastened, so that the angle may be maintained as high as is consistent with a safe pull. Since each kite adds to the strain upon the wire below it, latterly the lower portion of the main line has been composed of wire 0.038 inch in diameter that possesses a tensile strength of 390 pounds. The Richard meteorograph, contained in an aluminum cage of about a foot cube, weighs less than 3 pounds, and it is only necessary to screen the thermometer from the sun's rays to obtain the true temperature of the air, since the wind insures a circulation of air around the thermometer. Another meteorograph constructed by Mr. Fergusson records the velocity of the wind on the same drum with the three other elements, and weighs no more than the French instrument. It is shown in fig. 4 (Pl. II), and fig. 5 (Pl. III) is a facsimile record, two-thirds actual size.

The reeling apparatus is an example of how the same apparatus may serve diametrically opposite purposes. In sounding the depths of the ocean the wire must be pulled upward, whereas in sounding the heights of the atmosphere the wire must be pulled in the reverse direction. Therefore the deep-sea sounding apparatus has been altered by Mr. Fergusson to pull obliquely downward, the wire passing over a swiveling pulley, which follows its direction and registers on a dial the exact length unreeled. Next the wire bears against a pulley carried by a strong spiral spring, by which the pull upon it at all times is recorded on a paper-covered drum turned by clockwork, then it passes several times around a strain pulley, and finally is coiled under slight tension upon a large storage drum. When the kites are to be pulled down, the strain pulley is connected with a 2-horsepower steam engine, and the wire is drawn in at a speed of from 3 to 6 miles an hour, but when the kites are rising the belt is removed and the pull of the kites unreels the wire.

The method of making a kite flight for meteorological purposes at Blue Hill is as follows: A kite, fastened to a ring at the end of the main wire, and the meteorograph clamped to the wire being in the air, another kite is attached by a cord and the clamp described. The kites are then allowed to rise and to unreel the wire until its angle above the horizon becomes low, when other kites are added, the number depending on the size of the kites and the strength of the wind. After a pause at the highest attainable altitude, the reel is connected with the steam engine and the kites are drawn down. The pauses at the highest point, and when kites are attached or detached, are necessary to allow the recording instruments to acquire the conditions of the surrounding air, and because at these times the meteorograph is nearly stationary, measurements of its angular elevations are made with a surveyor's transit, while observations of azimuth give the direction of the wind at the different heights. The time of making each angular measurement is noted, so that the corresponding point on the trace of the meteorograph may be found. From the length of wire and its angular elevation the height of the meteorograph can be calculated, it having been found that the sag of the wire, or its deviation either in a vertical or a horizontal plane from the straight line joining kite and reel, does not cause an error exceeding 3 per cent in the height so computed. When the meteorograph is hidden by clouds, the height above the last point trigonometrically determined is computed from the barometric record by Laplace's formula. At night there is only the barometer from which to determine the height, for, although an attempt was made to use a lantern to sight upon, yet it soon becomes invisible, or, when seen, is confounded with the stars. Before and after the flight the thermometer and hygrometer of the meteorograph are compared with the standard instruments.

Since the use of wire and more efficient kites the heights have been greatly increased. Thus the average height above the sea attained by the meteorograph in the thirty-five flights made during 1898 was more than a mile and a third, whereas the average height of all the ascents prior to 1897 was less than half a mile. The extreme height of 15,807 feet, reached in July, 1900, exceeds the altitude of Mont Blanc, and also the greatest height at which meteorological observations have been made with a balloon in the United States. The progress upward each year is shown in this table:

Heights above sea level of kite flights at Blue Hill.

[Blue Hill is 630 feet above the sea.]

Year.	Number of records.	Heights, in feet.		Percentages of records above—					
		Mean of maximum.	Absolute maximum.	500 meters (1,640 feet).	1,000 meters (3,280 feet).	1,500 meters (4,920 feet).	2,000 meters (6,560 feet).	3,000 meters (9,840 feet).	4,000 meters (13,123 feet).
1894	2	1,860	2,070	50	0	0	0	0	0
1895	28	1,613	2,490	59	0	0	0	0	0
1896	86	2,772	9,327	78	28	9	4	0	0
1897	38	4,557	11,716	95	68	45	21	5	0
1898	35	7,350	12,070	100	92	80	66	20	0
1899	25	7,402	12,441	100	94	80	56	28	0
1900	24	8,451	15,807	100	96	85	67	38	8

The average of the highest points recorded in each one of the flights during August, 1898, exceeded a mile and a half, and on August 26 the meteorograph was raised 11,440 feet above Blue Hill, or 12,070 feet above the neighboring ocean. The meteorograph was suspended from the topmost kite, one of the Lamson pattern, having 71 square feet of lifting surface, and this was increased to a total of 149 square feet by four kites of the modified Hargrave type that were attached at intervals to the wire. The 5 miles of wire in the air weighed 75 pounds, and the total weight lifted, including kites and apparatus, was 112 pounds. The meteorograph left the ground at

10.40 a. m., attained its greatest height at 4.15 p. m., and returned to the ground at 8.40 p. m., its automatic record being shown in fig. 5, in which the heights are expressed in meters and the wind velocities in meters per second. The cumulus clouds were traversed three-quarters of a mile from the earth, and above them the air was found to be very dry. On the hill the air temperature was 72°, when it was 38° in the free air 11,440 feet above, and the wind velocity increased from 22 to 40 miles an hour as can be computed from the scale of miles on the right-hand margin of the anemometer record.

During the past six years, about two hundred and forty records have been obtained at Blue Hill in all kinds of weather conditions, from the ground up to 15,000 feet above it. They are published and discussed in the Annals of the Astronomical Observatory of Harvard College, Vol. xlii, Part I, and in several Bulletins of the Blue Hill Observatory, and constitute, no doubt, the most thorough study of the lower air yet made at a single station. The vertical distribution of temperature and humidity has been investigated and six types have been deduced. Normally, in fine weather, with increase of height the temperature decreases at the adiabatic rate for unsaturated air (1° F. for 183 feet) up to a certain height where there is a sudden rise of temperature, and above that height the decrease is slower. This rise, which is caused by a warm current overflowing a colder one, is noted by aeronauts also at greater heights. Owing to the chilling of the air near the ground at night it frequently happens that it is warmer at the height of a thousand feet than it is at the ground, and as the relative humidity aloft is generally the reverse of what it is at the ground, it follows that at certain heights in the free atmosphere the nights are warm and dry while the days are cold and damp. Contrary to the observations on mountains, the diurnal period of temperature usually disappears above a mile, but the changes due to cold and warm waves occur simultaneously at the ground and at the extreme heights reached by the kites. The observations obtained during the passage of cyclones and anticyclones indicate that the cause of the cyclone, at least in our latitude, is its higher temperature with respect to the surrounding air. This conclusion agrees with the convectional theory of Espy and Ferrel, but it is possible that the shallow cyclones felt at the earth's surface may have superposed on them other cyclones with cold centers.

Atmospheric electricity is noticeable since the use of wire as a flying line whenever the kites rise higher than a quarter of a mile above the ground. Usually the wire becomes strongly charged with electricity when great heights are reached and this is discharged in bright sparks at the reel. The potential generally increases with altitude, and probably the electricity is sometimes positive and sometimes negative, although no measurements have been made with the kites very high.

Notwithstanding its intensity the quantity of electricity in the atmosphere appears insufficient to warrant its collection and storage for practical purposes.

During the summer of 1898 the United States Weather Bureau undertook to obtain daily from seventeen stations equipped with kites (situated chiefly in the Mississippi Valley), automatic records at a height of about a mile, with which to draw a synoptic chart of the upper air for forecasting in connection with a similar chart of surface observations. The high-level chart could not be drawn regularly on account of light winds at some stations, but much data concerning temperature gradients were obtained, and these have been published. Since the work at Blue Hill was made known to foreign meteorologists, who have received drawings and models of our apparatus, the use of kites to obtain meteorological data has been taken up extensively on the Continent of Europe, and already the meteorological bureaus of France, Germany, and Russia have established departments for the purpose of obtaining observations in the free air with both kites and balloons.

Whenever there is wind, kites possess advantages over any other method of exploring the air up to the height of at least 15,000 feet. Although only on mountains can observations at a uniform height be maintained continuously, yet the conditions there are not those of the free air at an equal height. Observations in a drifting balloon are affected by the heated or stagnant air accompanying the balloon, and the progressive changes in the atmospheric conditions at one place can not be studied, because, generally, these observations are not comparable with simultaneous observations made at one station on the ground. With kites, however, frequent ascents and descents permit the true conditions prevailing in superposed strata of air at definitely known heights to be obtained nearly simultaneously. Kites can rise much higher than captive balloons, which are borne down by the weight of the cable necessary to control them. Finally, kites cost very much less than either mountain stations or balloons. It appears, therefore, that in future the equipment of a first-class meteorological observatory should include the kite (and perhaps the German kite-balloon for use when the wind is lacking), so that automatic records may be obtained daily at the height of a mile or two in the free air, at the same time that similar observations are made at the ground.

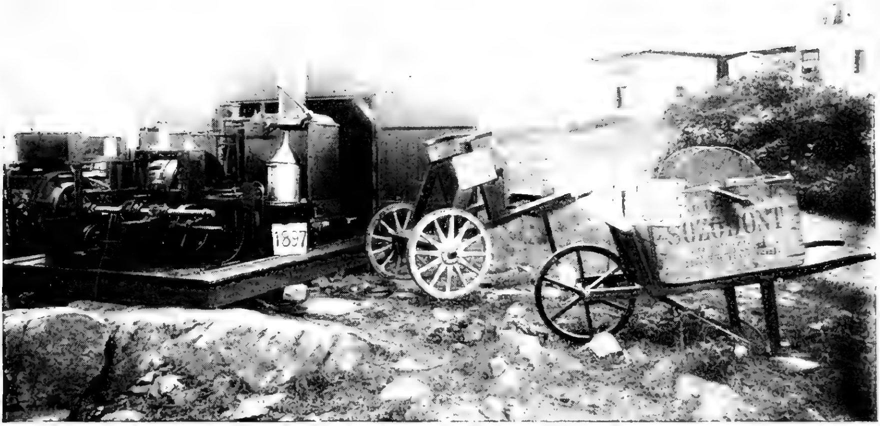

FIG. 1.—EVOLUTION OF THE KITE-REEL.

FIG. 2.—MODIFIED HARGRAVE KITE.

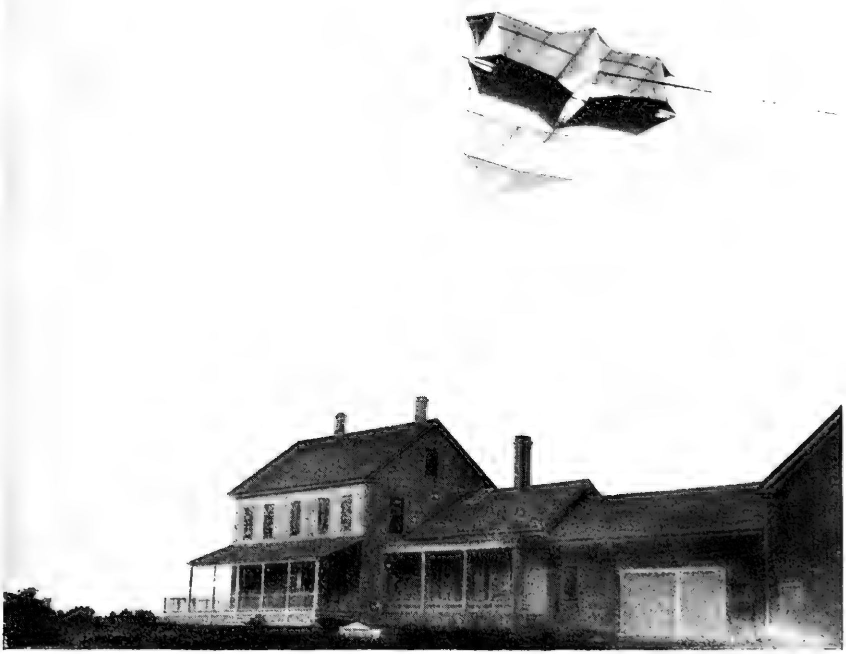

FIG. 3.—LAMSON'S AERO-CURVE KITE.

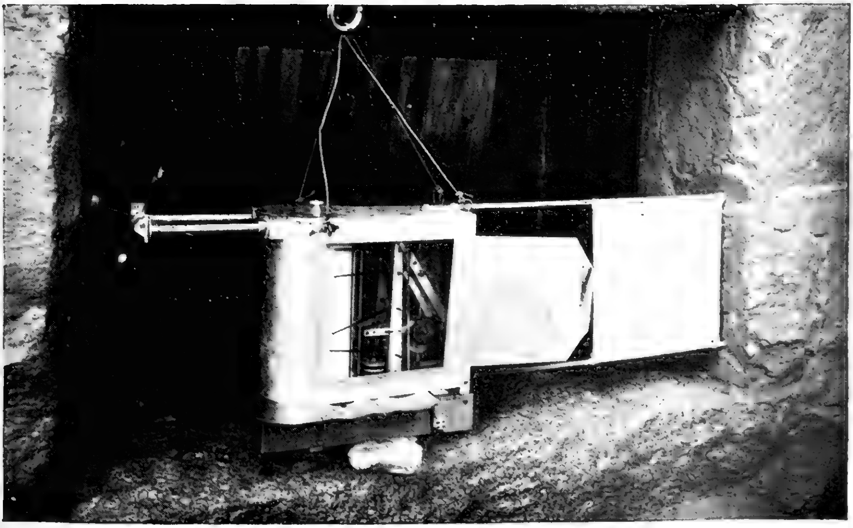

FIG. 4.—FERGUSSON'S KITE-METEOROGRAPH.

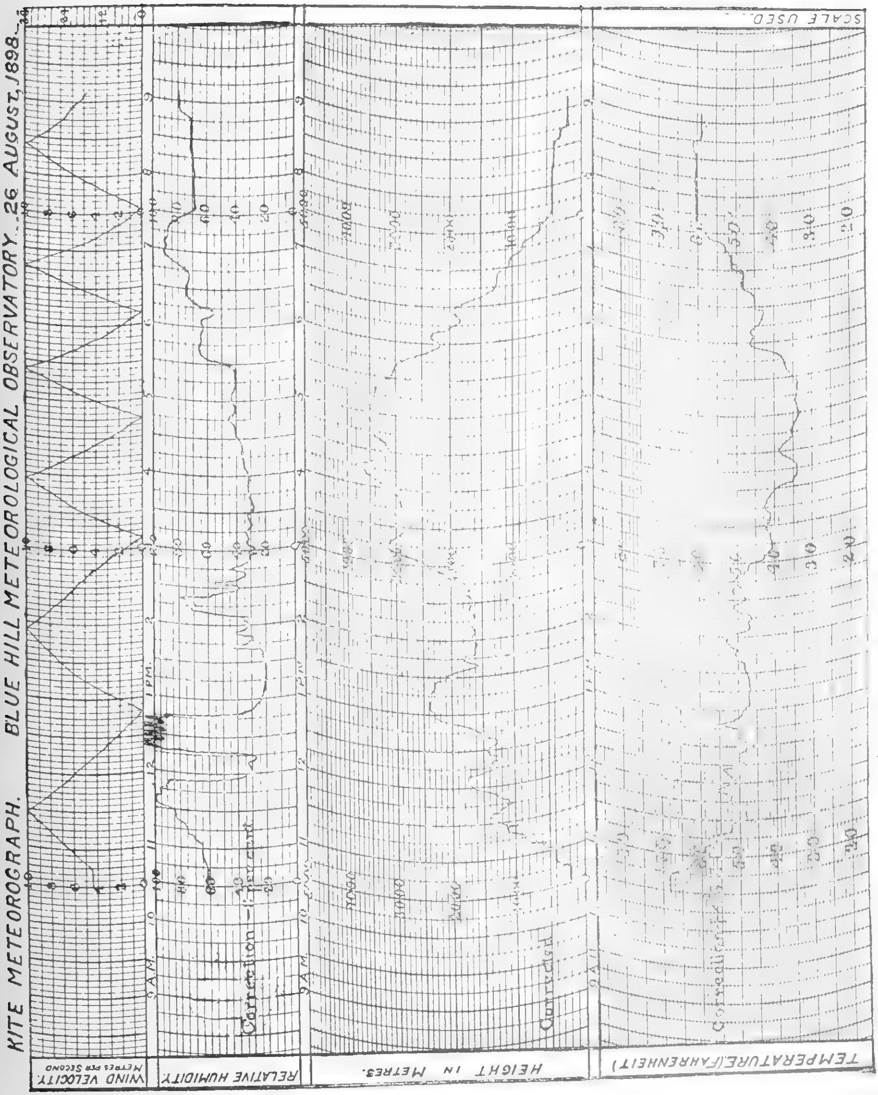

FIG. 5.—METEOROGRAM OF A HIGH KITE-FLIGHT.

PROGRESS IN CHEMISTRY IN THE NINETEENTH CENTURY.[1]

By Prof. WILLIAM RAMSAY.

The progress of the science of chemistry forms one phase of the progress of human thought. While at first mankind was contented to observe certain phenomena, and to utilize them for industrial purposes if they were found suitable, "philosophers," as the thinking portion of our race loved to call themselves, have always attempted to assign some explanation for observed facts and to group them into similars and dissimilars. It was for long imagined, following the doctrines of the Greeks and of their predecessors, that all matter consisted of four elements or principles, names which survive to this day in popular language. These were "fire," "air," "water," and "earth." It was not until the seventeenth century that Boyle in his Sceptical Chymist (1661) laid the foundations of the modern science by pointing out that it was impossible to explain the existence of the fairly numerous chemical substances known in his day, or the changes which they can be made to undergo, by means of the ancient Greek hypotheses regarding the constitution of matter. He laid down the definition of the modern meaning of the word "element;" he declined to accept the current view that the properties of matter could be modified by assimilating the qualities of fire, air, earth, or water, and he defined an element as the constituent of a compound body. The first problem, then, to be solved was to determine which of the numerous forms of matter were to be regarded as elementary, and which are compound, or composed of two or more elements in a state of combination, and to produce such compounds by causing the appropriate elements to unite with each other.

ANCIENT IDEAS ABOUT THE AIR.

One of the first objects to excite curiosity and interest was the air which surrounds us, and in which we live and move and have our being. It was, however, endowed with a semispiritual and scarcely corporeal nature in the ideas of our ancestors, for it does not affect

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the senses of sight, smell, or taste, and though it can be felt, yet it eludes our grasp. The word gas, moreover, was not invented until Van Helmont devised it to designate various kinds of "airs" which he had observed. The important part which gases play in the constitution of many chemical compounds was accordingly overlooked, and, indeed, it appeared to be almost as striking a feat of necromancy to produce a quantity of gas of great volume from a small pinch of solid powder as for a "Jinn" of enormous stature but of delicate texture to issue from a brass pot, as related in the Arabian Nights Entertainments. Gradually, however, it came to be recognized, not merely that gases have corporeal existence, but that they even possess weight. This, though foreshadowed by Torricelli, Jean Rey, and others, was first clearly proved by Black, professor of chemistry in Edinburgh, in 1752, through his masterly researches, as carbonic acid.

The ignorance of the material nature of gases and of their weight lies at the bottom of the phlogistic theory, a theory devised by Stahl about the year 1690, to account for the phenomena of combustion and respiration and the recovery or "reduction" of metals from their "earths" by heating with charcoal or allied bodies. According to this inverted theory, a substance capable of burning was imagined to contain more or less phlogiston, a principle which it parted with on burning, leaving an earth deprived of phlogiston, or "dephlogisticated" behind if a metal. This earth when heated with substances rich in phlogiston, such as coal, wood, flour, and similar bodies, recovered the phlogiston, which it had lost on burning, and with the added phlogiston its metallic character. Other substances, such as phosphorus and sulphur, gave solids or acid liquids to which phlogiston was not so easy to add; but even they could be rephlogisticated. On this hypothesis, it was the earths, and such acid liquids as sulphuric or phosphoric acids which were the elements; the metals and sulphur and phosphorus were their compounds with phlogiston.

DISCOVERY OF OXYGEN.

The discovery of oxygen by Priestley and by Scheele in 1774, and the explanation of its functions by Lavoisier during the following ten years gave their true meaning to these phenomena. It was then recognized that combustion was union with oxygen; that an "earth" or "calx" was to be regarded as the compound of a metal with oxygen; that when a metal becomes tarnished and converted into such an earthy powder it is being oxidized; that this oxide, on ignition with charcoal or carbon, or with compounds such as coal, flour, or wood, of which carbon is a constituent, gives up its oxygen to the carbon, forming an oxide of carbon, carbonic oxide, on the one hand, or carbonic "acid" on the other, while the metal is reproduced in its "reguline" or metallic condition, and that the true elements are metals, carbon, sulphur, phosphorus, and similar bodies, and not the products of their oxidation.

The discovery that air is, in the main, a mixture of nitrogen, an inert gas, and oxygen, an active one, together with a small proportion of carbonic "acid" (or, as it is now termed, anhydride)—a discovery perfected by Rutherford, Black, and Cavendish—and that water is a compound with oxygen of hydrogen, previously known as inflammable air, by Cavendish and by Watt, finally overthrew the theory of phlogiston, but at the beginning of this century it still lingered on, and was defended by Priestley until his death in 1804. Such, in brief, was the condition of chemical thought in the year 1800. Scheele had died in 1786, at the early age of 44; Lavoisier was one of the victims of the French Revolution, having been guillotined in 1794; Cavendish had ceased to work at chemical problems and was devoting his extraordinary abilities to physical problems of the highest importance, while living the life of an eccentric recluse; and Priestley, driven by religious persecution from England to the more tolerant shores of America, was enjoying a peaceful old age, enlivened by occasional incursions into the region of sectarian controversy.

FIRST STRIKING DISCOVERY OF THE CENTURY.

The first striking discovery of our century was that of the compound nature of alkalies and of the alkaline earths. This discovery was made by Humphry Davy. Born in Cornwall in 1778, he began the study of chemistry, self-taught, in 1796, and in 1799 he became director of the Pueumatic Institution, an undertaking founded by Dr. Beddoes at Bristol for the purpose of experiments on the curative effects of gases in general. Here he at once made his mark by the discovery of the remarkable properties of "laughing gas," or nitrous oxide. At the same time he constructed a galvanic battery, and began to perform experiments with it in attempting to decompose chemical compounds by its means. In 1801 Davy was appointed professor of chemistry at the Royal Institution, a society or club which had been founded a few years previously by Benjamin Thomson, Count Rumford, for the purpose of instructing and amusing its members with recent discoveries in chemistry and natural philosophy. In 1807 Davy applied his galvanic battery to the decomposition of damp caustic potash and soda, using platinum poles. He was rewarded by seeing globules of metal, resembling mercury in appearance, at the negative pole, and he subsequently proved that these globules, when burned, reproduced the alkali from which they had been derived. They also combined with "oxymuriatic acid," as chlorine (discovered by Scheele) was then termed, forming ordinary salt, if sodium be employed, and the analogous salt, "muriate of potash," if the allied metal, potassium, were subjected to combustion. By using mercury as the negative pole, and passing a current through a strong solution of the chloride of calcium, strontium, or barium, Davy succeeded in procuring mixtures with mercury or "amalgams" of their metals, to which he gave the names calcium, strontium, and barium. Distillation removed most of the mercury, and the metal was left behind in a state of comparative purity. The alkali metals, potassium and sodium, were found to attack glass, liberating the "basis of the silex," to which the name silicon has since been given.

Thus nearly the last of the "earths" had been decomposed. It was proved that not merely were the "calces" of iron, copper, lead, and other well-known metals compounds of the respective metals with oxygen, but Davy showed that lime and its allies, strontia and baryta, and even silica or flint, were to be regarded as oxides of elements of metallic appearance. To complete our review of this part of the subject, suffice it to say that aluminum, a metal now produced on an industrial scale, was prepared for the first time in 1827 by Wöhler, professor of chemistry at Göttingen, by the action of potassium on its chloride, and alumina, the earthy basis of clay, was shown to be the oxide of the metal aluminum. Indeed, the preparation of this metal in quantity in now carried out at Schaffhausen-on-the-Rhine and at the Falls of Foyers in Scotland by electrolysis of the oxide dissolved in melted cryolite, a mineral consisting of the fluorides of sodium and aluminum, by a method differing only in scale from that by means of which Davy isolated sodium and potassium in 1806.

DAVY'S IMPORTANT WORK.

To Davy, too, belongs the merit of having dethroned oxygen from its central position among the elements. Lavoisier gave to this important gas the name "oxygen," because he imagined it to be the constituent of all acids. He renamed the common compounds of oxygen in such a manner that the term oxygen was not even represented in the name—only inferred. Thus a "nitrate" is a compound of an oxide of nitrogen and an oxide of a metal; a "sulphate," of the oxide of a metal with one of the oxides of sulphur, and so on. Davy, by discovering the elementary nature of chlorine, showed first that it is not an oxide of hydrochloric acid (or muriatic acid, as it was then called); and, second, that the latter acid is a compound of the element chlorine with hydrogen. This he did by passing chlorine over white-hot carbon—a substance eminently suited to deprive oxy-compounds of their oxygen—and proving that no oxide of carbon is thereby produced; by acting on certain chlorides, such as those of tin or phosphorus with ammonia, and showing that no oxide of tin or phosphorus is formed; and, lastly, by decomposing "muriatic acid gas" (gaseous hydrogen chloride) with sodium and showing that the only product besides common salt is hydrogen. Instead, therefore, of the former theory that a chloride was a compound of the unknown basis of oxymuriatic acid with oxygen and the oxide of a metal, he introduced the simpler and correct view that a chloride is merely a compound of the element chlorine with a metal. In 1813 he established the similar nature of fluorine, pointing out that on the analogy of the chlorides it was a fair deduction that the fluorides are compounds of an undiscovered element, fluorine, with metals; and that hydrofluoric acid is the true analogue of hydrochloric acid. The truth of this forecast has been established of recent years by Henri Moissan, who isolated gaseous fluorine by subjecting a mixture of hydrofluoric acid and hydrogen potassium fluoride contained in a platinum U tube to the action of a powerful electric current. He has recently found that the tube may be equally well constructed of copper; and this may soon lead to the industrial application of the process. The difficulty of isolating fluorine is due to its extraordinary chemical energy, for there are few substances, elementary or compound, which resist the action of this pale, yellow, suffocating gas. In 1811 iodine, separated by Courtois from the ashes of sea plants, was shown by Davy to be an element analogous to chlorine. Gay-Lussac subsequently investigated it and prepared many of its compounds; and in 1826 the last of these elements, bromine, was discovered in the mother liquor of sea salt by Balard. The elements of this group have been termed "halogens," or "salt producers."

JOHN DALTON'S THEORY.

While Davy was pouring his researches into the astonished ears of the scientific and dilettante world John Dalton, a Manchester schoolmaster, conceived a theory which has proved of the utmost service to the science of chemistry, and which bids fair to outlast our day. It had been noticed by Wenzel, by Richter, by Wollaston, and by Cavendish toward the end of the last century that the same compounds contain the same constituents in the same proportions, or, as the phrase runs, "possess constant composition." Wollaston, indeed, had gone one step further, and had shown that when the vegetable acid, oxalic acid, is combined with potash it forms two compounds, in one of which the acid is contained in twice as great an amount relatively to the potash as in the other. The names monoxalate and binoxalate of potash were applied to these compounds to indicate the respective proportions of the ingredients. Dalton conceived the happy idea that by applying the ancient Greek conception of atoms to such facts the relative weights of the atoms could be determined. Illustrating his views with the two compounds of carbon with hydrogen, marsh gas and olefiant gas, and with the two acids of carbon, carbonic oxide and carbonic "acid," he regarded the former as a compound of one atom of carbon and one of hydrogen and the second as a compound of one atom of carbon and two of hydrogen, and similarly for the two oxides of carbon. Knowing the relative weights in which these elements enter into combination, we can deduce the relative weights of the atoms. Placing the relative weight of an atom of hydrogen equal to unity, we have:

	Marsh gas.	Olefiant gas.		Carbonic oxide.	Carbonic acid.
Carbon	6	6	Carbon	5	6
Hydrogen ...	1	2	Oxygen	8	16

Thus the first compound, marsh gas, was regarded by Dalton as composed of an atom of carbon in union with an atom of hydrogen; or, to reproduce his symbols, as ◍ ⊙, while the second, olefiant gas, on this hypothesis, was a compound of two atoms of hydrogen with one of carbon, or ⊙ ◍ ⊙. Similarly the symbols ◍ ○ and ○ ◍ ○ were given to the two compounds of carbon with oxygen. So water was assigned the symbol ⊙ ○, for Dalton imagined it to be a compound of one atom of hydrogen with one of oxygen. Compounds containing only two atoms were termed by him "binary;" those containing three, "ternary;" four, "quaternary," and so on. The weight of an atom of oxygen was eight times that of an atom of hydrogen, while that of an atom of carbon was six times as great as the unit. By assigning symbols to the elements, consisting of the initial letters of their names, or of the first two letters, formulæ were developed, indicating the composition of the compound, the atomic weights of the elements being assured. Thus, NaO signified a compound of an atom of sodium (natrium) weighing twenty-three times as much as a similar atom of hydrogen with an atom of oxygen possessing eight times the weight of an atom of hydrogen. Therefore, 31 pounds of soda should consist of 23 pounds of sodium in combination with 8 pounds of oxygen, for, according to Dalton, each smallest particle of soda contains an atom of each element, and the proportion is not changed however many particles may be considered.

It has been pointed out by Judge Stallo, of Philadelphia, in his Concepts of Physics that such an hypothesis as that of Dalton is no explanation; that a fact of nature, as, for example, the fact of simple and multiple proportions, is not explained by being minified. Allowing the general truth of this statement, it is nevertheless undoubted that chemistry owes much to Dalton's hypothesis; a lucky guess at first, it represents one of the fundamental truths of nature, although its form must be somewhat modified from that in which Dalton conceived it. Dalton's work was first expounded by Thomas Thomson, professor at Glasgow, in his System of Chemistry, published in 1805, and subsequently in Dalton's own New System of Chemical Philosophy, the three volumes of which were published in 1808, in 1810, and in 1827.

"ATOMIC WEIGHTS."

The determination of these "constants of nature" was at once followed out by many chemists, Thomson among the first. But chief among the chemists who have pursued this branch of work was Jacob Berzelius, a Swede, who devoted his long life (1779–1848) to the manufacture of compounds and to the determination of their composition, or, as it is still termed, the determination of the "atomic weights"—more correctly, "equivalents"—of the elements of which they are composed. It is to him that we owe most of our analytical methods, for prior to his time there were few, if any, accurate analyses. Although Lavoisier had devised a method for the analysis of compounds of carbon, viz, by burning the organic compounds in an atmosphere of oxygen contained in a bell jar over mercury and measuring the volume of carbon dioxide produced, as well as that of the residual oxygen, Berzelius achieved the same results more accurately and more expeditiously by heating the substance, mixed with chlorate of potassium and sodium chloride, and then estimating the hydrogen as well as the carbon. This process was afterwards perfected by Liebig. Berzelius, however, was able to show that compounds of carbon, like those of other elements, were instances of combination in constant and multiple proportions.

In 1815 two papers were published in the Annals of Philosophy by Dr. Prout which have had much influence on the progress of chemistry. They dealt with the figures which were being obtained by Thomson, Berzelius and others, at that time supposed to represent the "atomic weights" of the elements. Prout's hypothesis, based on only a few numbers was that the atomic weights of all elements were multiples of that of hydrogen, taken as a unity. There was much dispute regarding this assertion at the time, but as it was contradicted by Berzelius's numbers the balance of opinion was against it. But about the year 1840 Dumas discovered an error in the number (12.12) given by Berzelius as the atomic weight of carbon; and with his collaborator, Stas, undertook the redetermination of the atomic weights of the commoner elements—for example, carbon, oxygen, chlorine, and calcium. This line of research was subsequently pursued alone by Stas, whose name will always be remembered for the precision and accuracy of his experiments. At first Dumas and Stas inclined to the view that Prout's hypothesis was a just one, but it was completely disproved by Stas's subsequent work, as well as by that of numerous other observers. It is nevertheless curious that a much larger proportion of the atomic weights approximate to whole numbers than would be foretold by the doctrine of chances, and perhaps the last has not been heard of Prout's hypothesis, although in its original crude form it is no longer worthy of credence.

ATOMS AND MOLECULES.

One of the most noteworthy of the discoveries of the century was made by Gay-Lussac (1778–1850) in the year 1808. In conjunction with Alexander von Humboldt, Gay-Lussac had rediscovered about three years before what had previously been established by Cavendish, namely, that, as nearly as possible, 2 volumes of hydrogen combine with 1 volume of oxygen to form water, the gases having been measured at the same temperature and pressure. Humboldt suggested to Gay-Lussac that it would be well to investigate whether similar simple relations exist between the volumes of other gaseous substances when they combine with each other. This turned out to be the case; it appeared that almost exactly 2 volumes of carbonic oxide unite with 1 volume of oxygen to form carbon dioxide; that equal volumes of chlorine and hydrogen unite to form hydrochloric acid gas; that 2 volumes of ammonia gas consist of 3 volumes hydrogen in union with 1 volume of nitrogen, and so on. From such facts, Gay-Lussac was led to make the statement that: The weights of equal volumes of both simple and compound gases, and, therefore, their densities, are proportional to their empirically found combining weights, or to rational multiples of the latter. Gay-Lussac recognized this discovery of his to be a support for the atomic theory; but it did not accord with many of the then received atomic weights. The assumption that equal volumes of gases contain equal numbers of particles, or, as they were termed by him, molécules intégrantes, was made in 1811 by Avogadro, professor of physics at Turin (1776–1856). This theory, which has proved of the utmost importance to the sciences both of physics and of chemistry, had no doubt occurred to Gay-Lussac, and had been rejected by him for the following reasons: A certain volume of hydrogen, say 1 cubic inch, may be supposed to contain an equal number of particles (atoms) as an equal volume of chlorine. Now, these two gases unite in equal volumes. The deduction appears so far quite legitimate that 1 atom of hydrogen has combined with 1 atom of chlorine. But the resulting gas occupies 2 cubic inches, and must, therefore, contain the same number of particles of hydrogen chloride, the compound of the two elements, as 1 cubic inch originally contained of hydrogen or of chlorine. Thus we have 2 cubic inches containing, of uncombined gases, twice as many particles as is contained in that volume after combinations. Avogadro's hypothesis solved the difficulty. By premising two different orders of particles, now termed atoms and molecules, the solution was plain. According to him, each particle, or molecule, of hydrogen is a complex, and contains 2 atoms; the same is the case with chlorine. When these gases combine, or rather react, to form hydrogen chloride, the phenomenon is one of a change of partners; the molecule, the double atom, of hydrogen splits; the same is the case with the molecule of chlorine; and each liberated atom of hydrogen unites with a liberated atom of chlorine, forming a compound, hydrogen chloride, which equally consists of a molecule, or double atom. Thus 2 cubic inches of hydrogen chloride consist of a definite number of molecules, equal in number to those contained in a cubic inch of hydrogen, plus those contained in a cubic inch of chlorine. The case is precisely similar if other compounds of gases be considered.

Berzelius was at first inclined to adopt this theory, and indeed went so far as to change many of his atomic weights to make them fit it. But later he somewhat withdrew from his position, for it appeared to him that it was hazardous to extend to liquids and solids a theory which could be held only of gases. Avogadro's suggestion therefore rested in abeyance until the publication in 1858 by Cannizzaro, now professor of chemistry in Rome, of an essay in which all the arguments in favor of the hypothesis were collected and stated in a masterly manner. It will be advisable to revert to this hypothesis at a later point and to consider other guides for the determination of atomic weights.

EQUAL CAPACITY FOR HEAT.

In 1819, Dulong (1785–1838), director of the École Polytechnique at Paris, and Petit (1791-1820), professor of physics there, made the discovery that equal amounts of heat are required to raise equally the temperature of solid and liquid elements, provided quantities are taken proportional to their atomic weights. Thus, to raise the temperature of 56 grams of iron through 1 degree requires approximately the same amount of heat as is required to raise through 1 degree 32 grams of sulphur, 63.5 grams of copper, and so on, these numbers representing the atomic weights of the elements named. In other words, equal numbers of atoms have equal capacity for heat. The number of heat units or calories (one calory is the amount of heat required to raise the temperature of 1 gram of water through 1° C.) which is necessary to raise the atomic weight expressed in grams of any solid or liquid element through 1° C. is approximately 6.2. It varies between 5.7 and 6.6 in actual part. This affords a means of determining the true value of the atomic weight of an element, as the following example will show: The analysis of the only compound of zinc and chlorine shows that it contains 47.49 per cent of zinc and 52.16 per cent of chlorine. Now, 1 grain of hydrogen combines with 35.5 grains of chlorine to form 36.5 grains of hydrogen chloride; and, as already remarked, 1 volume of hydrogen and 1 volume of chlorine combine, forming 2 volumes of hydrogen chloride. Applying Avogadro's hypothesis, 1 molecule of hydrogen and 1 molecule of chlorine react to yield 2 molecules of hydrogen chloride, and as each molecule is supposed to consist in this case of 2 atoms, hydrogen chloride consists of 1 atom of each of its constituent elements. The amount of that element therefore which combines with 35.5 grains of chlorine may give the numerical value of the atomic weight of the element if the compound contains 1 atom of each element. In that case the formula of the above compound would be ZnCl and the atomic weight of zinc 32.7; but if the formula is $ZnCl_2$ the atomic weight of zinc would be 32.7×2; if $ZnCl_3$, 32.7×3, and so on. The specific heat of metallic zinc enables this question to be solved. For it has been found experimentally to be about 0.095, and $6.2 \div 0.095 = 65.2$, a close approximation to $32.7 \times 2 = 65.4$. The conclusion is therefore drawn that zinc chloride is composed of 1 atom of zinc in combination with 2 atoms of chlorine, that the atomic weight of zinc is 65.4, and that the molecular weight of zinc chloride is $65.4 + (35.5 \times 2) = 136.4$. Inasmuch as the relative weight of a molecule of hydrogen is 2 (that of an atom being 1) zinc chloride in the gaseous state should be $136.4 \div 2 = 68.2$ times that of hydrogen, measured at the same temperature and pressure. This has been found experimentally to be the case.

The methods of determining the vapor densities, or relative weights of vapors, are three in number. The first method, due to Dumas (1827), consists in vaporizing the substance in question in a bulb of glass or of porcelain, at a known temperature, closing the bulb while still hot and weighing it after it is cold. Knowing the capacity of the bulb, the weight of hydrogen necessary to fill it at the desired temperature can be calculated and the density of the vapor thus arrived at. A second method was devised by Gay-Lussac and perfected by A. W. Hofmann (1868), and a third, preferable for its simplicity and ease of execution, is due to Victor Meyer (1881).

In 1858, as already remarked, Cannizzarro showed the connection between these known facts, and for the first time attention was called to the true atomic weights, which were up to that time confused with equivalents, or weights of elements required to replace one unit weight of hydrogen. These were generally regarded as atomic weights by Dalton and his contemporaries.

EXCEPTIONS TO THE LAW.

Some exceptions had been observed to the law of Dulong and Petit, viz, beryllium or glucinium, an element occurring in emeralds; boron, of which borax is a compound; silicon, the component of quartz and flint, and carbon. It was found by Weber that at high temperatures the specific heats of these elements are higher, and the atomic heats approximate to the number of 6.2; but this behavior is not peculiar to these elements, for it appears that the specific heat of all elements increases with rise of temperature.

A certain number of exceptions have also been noticed to the law of Gay-Lussac, which may be formulated: The molecular weight of a compound in a gaseous state is twice its density referred to hydrogen. Thus equal volumes of ammonia and hydrogen chloride unite to form ammonium chloride. It was to be expected that the density should be half the molecular weight, thus:

$NH_3+HCl=NH_4Cl$; and $53.5 \div 2=26.75=$density. (14+3) (1+35.5)
53.5.

But the density actually found is only half that number, viz, 13.37; and for long this and similar cases were supposed to be exceptions to the law of Gay-Lussac, viz, that equal volumes of gases at the same pressure expand equally for equal rise of temperature. In other instances the gradual decrease in density with rise of temperature can be followed, as with chloral hydrate, the products of which are chloral and water.

It was recognized by St. Claire Deville (1857) that the decrease in density of such mixtures of gases was due, not to their being exceptions to Avogadro's law, but to the gradual decomposition of the compound body with rise of temperature. To this gradual decomposition he gave the name dissociation. This conception has proved of the utmost importance to the science, as will be seen in the sequel. To take the above instance of ammonium chloride, its abnormal density is due to its dissociation into ammonia and hydrogen chloride; and the gas which is obtained on raising its temperature consists, not of gaseous ammonium chloride, but of a mixture of ammonia and hydrogen chloride, which, as is easily seen, occupy, when separate, twice the volume that would be occupied by the gaseous compound. Of recent years it has been shown by Brereton Baker that, if perfectly free from moisture, ammonium chloride gasifies as such, and that its density in the state of vapor is in fact 26.75.

The molecular complexity of gases has thus gradually become comprehended, and the truth of Avogadro's law has gained acceptance. And as a means of picturing the behavior of gaseous molecules the kinetic theory of gases has been devised by Joule, Clausius, Maxwell, Thomson (Lord Kelvin), and others. On the assumption that the pressure of a gas on the walls of the vessel which contains it is due to the continued impacts of its molecules, and that the temperature of a gas is represented by the product of the mass of the molecules, or the square of their velocity, it has been possible to offer a mechanical explanation of Boyle's law, that at constant temperature the volume of a gas diminishes in proportion as the pressure increases; of Gay-Lussac's law, that all gases expand equally for equal rise of temperature, provided pressure is kept constant; the condition being that equal volumes of gases contain equal numbers of molecules. A striking support is lent to this chain of reasoning by the facts discovered by Thomas Graham (1805–1869), professor at University College, London, and subsequently master of the royal mint. Graham discovered that the rates of diffusion of gases into each other is inversely as the square roots of their densities. For instance, the density of hydrogen being taken as a unity, that of oxygen is sixteen times as great; if a vessel containing hydrogen be made to communicate with one containing oxygen, the hydrogen will pass into the oxygen and mix with it; and, conversely, the oxygen will pass into the hydrogen vessel. This is due to the intrinsic motion of the molecules of each gas. And Graham found experimentally that for each volume of oxygen which enters the hydrogen vessel four volumes of hydrogen will enter the oxygen vessel. Now, $4=\sqrt{16}$; and as these masses are relatively 1 and 16, and their temperatures are equal, the squares of their velocities are respectively 1 and 16.

COMPLEXITY OF LIQUID MOLECULES.

The question of molecular complexity of gases being thus disposed of, it remains to be considered what is the relative complexity of liquid molecules. The answer is indicated by a study of the capillary phenomena of liquids, one method of measuring which is the height of their ascent in narrow or capillary tubes. It is impossible in the space at our disposal to enter into detail as to the method and arguments necessary. Suffice it to say that the Hungarian physicist Eötvös was the first to indicate the direction of research, and that Ramsay and Shields succeeded in proving that the complexity of the molecules of most liquids is not greater than that of the gases which they form on being vaporized; and also that certain liquids, e. g., water, the alcohols, and other liquids, are more or less "associated;" i. e., their molecules occur in complexes of two, three, four, or more, and as the temperature is raised the complexity of molecular structure diminishes.

As regards the molecular complexity of solids nothing definite is known, and, moreover, there appears to be no method capable of revealing it.

ELECTRO-CHEMICAL THEORY.

While the researches of which a short account has now been given have led to knowledge regarding the nature of molecules, the structure of the molecule has excited interest since the early years of the century, and its investigation has led to important results. The fact of the decomposition of acidified water by an electric current, discovered by Nicholson and Carlisle, and of salts into "bases" and "acids" by Berzelius and Hisinger, in 1803, led to a belief that a close connection exists between electric energy or, as it was then termed, "electric force," and the affinity which holds the constituents of chemical compounds in combination. In 1807 Davy propounded the theory that all compounds consist of two portions, one electro-positive and the other electro-negative. This idea was the result of experiments on the behavior of substances such, for example, as copper and sulphur. If portions of these elements be insulated and then brought into contact, they become oppositely electrified. The degree of electrification is intensified by rise of temperature until, when combination ensues, the electrification vanishes. Combination, therefore, according to Davy, is concurrent with the equalization of potentials. In 1812 Berzelius brought forward an electro-chemical theory, which for the following twenty years was generally accepted. His primary assumption was that the atoms of elements or, in certain cases, groups of atoms are themselves electrified; that each atom or group of atoms possesses two poles—one positive, the other negative; that the electrification of one of these poles predominates over that of the other, so that the atom or group is itself, as a whole, electro-positive or electro-negative; that combination ensued between such oppositely electrified bodies by the neutralization, partial or complete, of their electric charges; and, lastly, that the polarity of an element or group could be determined by noting whether the element or group separated at the positive or the negative pole of the galvanic battery or electrolysis. For Berzelius, oxygen was the most electro-negative and potassium the most electro-positive of the elements, the bridge between the "nonmetals" and the "metals" being hydrogen, which, with nitrogen, forms a basic or electro-positive group, while with chlorine, etc., it forms electro-negative groups. The fact that an electric current splits compounds in solution into two portions led Berzelius to devise his "dualistic" system, which involved the assumption that all compounds consist of two portions, one electro-positive, the other electro-negative. Thus, sulphate of magnesium and potassium was to be regarded as composed of electro-positive potassium sulphate in combination with electro-negative magnesium sulphate; the former in its turn consisted of electro-negative sulphur trioxide (SO_3) in combination with electro-positive oxide of potassium (K_2O), while each of these proximate constituents of potassium sulphate were themselves composed of the electro-negative oxygen in combination with electro-positive sulphur or potassium. On contrasting sulphur with potassium, however, the former was considered more electro-negative than the latter; so that the group SO_3 as a whole was electro-negative, while K_2O was electro-positive. The symbols given above, which are still in universal use, were also devised by Berzelius for the purpose of illustrating and emphasizing his views. These views, however, met with little acceptance at the time in England.

OLD THEORIES LOSE GROUND.

Lavoisier's idea that oxygen was the necessary constituent of all acids began about this time to lose ground; for Davy had proved the elementary nature of chlorine, and hydrochloric acid, one of the strongest, was thus seen to contain no oxygen, and Davy expressed the view, founded on his observation, that iodic "acid," I_2O_5, was devoid of acid properties until dissolved in water, and that the essential constituent of all acids was hydrogen, not oxygen. The bearing of this theory on the dualistic theory is, that while, e. g., sulphuric acid was regarded by Berzelius as SO_3, containing no hydrogen, and was supposed to be separated as such at the positive pole of a battery, Davy's suggestion led to the opposite conclusion, that the formula of sulphuric acid is H_2SO_4, and that by the current it is resolved into H_2 and SO_4. Faraday's electrolytic law, that when a current is passed through electrolytes in solution the elements are liberated in quantities proportional to their equivalents, led to the abandonment of the dualistic theory. For when a current is passed in succession through acidified water, fused lead chloride, and a solution of potassium sulphate, the quantities of hydrogen and oxygen from the water, of lead and chlorin from the lead chloride, and the potassium of the sulphate are in accordance with Faraday's law. But in addition to the potassium there is liberated at the same pole an equivalent of hydrogen. Now, if Berzelius's theory be true, the products should be SO_3 and K_2O, but if the opposite view be correct, then K_2 is liberated first and by its subsequent action on water it yields potash, and its equivalent of hydrogen. This was pointed out first by Daniell, professor at King's College, London, and it was regarded as a powerful argument against Berzelius's system. In 1833, too, Graham investigated the phosphoric acids, and prepared the salts of three, to which he gave the names ortho-, pyro-, and meta- phosphoric acids. To understand the bearing of this on the doctrine of dualism it must be remembered that P_2O_5, pentoxide of phosphorus, was at that date named phosphoric acid. When dissolved in water, it reacts with bases, forming salts—the phosphates. But the quantity of water necessary was not then considered essential; Graham, however, showed that there exist three series of salts; one set derived from $P_2O_5, 3H_2O$; one from $P_2O_5, 2H_2O$, and a third from P_2O_5, H_2O. His way of stating the fact was that water could play the part of a base; for example, the ordinary phosphate of commerce possessed, according to him, the formula $P_2O_5, 2Na_2O, H_2O$; two-thirds of the "water of constitution" being replaced by oxide of sodium. Liebig, then professor at Giessen (1803–1873), founded on these and on similar observations of his own the doctrine of polybasic acids—acids in which one, two, three, or more atoms of hydrogen were replaceable by metals. Thus, instead of writing, as Graham did, $P_2O_5, 2Na_2O, H_2O$, he wrote PO_4Na_2H; and for orthophosphoric acid, PO_4H_3. The group of atoms (PO_4) therefore existed throughout the whole series of orthophosphates, and could exist in combination with hydrogen, with hydrogen and metals, or with metals alone. Similarly the group (P_2O_7) was characteristic of pyrophosphates and (PO_3) of metaphosphates, for $P_2O_5, 2H_2O\ (P_2O_7)\ H_4$; and $P_2O_5, H_2O=2(PO_3)H$.

CLEAR IDEAS OF THE STRUCTURE OF THE MOLECULE.

The first clear ideas of the structure of the molecule were, however, gained from the study of the compounds of carbon. It was difficult to apply the dualistic theory to them. For few of them are electrolytes, and therefore their products of electrolysis, being nonexistent, could not be classified. Nevertheless, Gay-Lussac regarded alcohol, C_2H_6O, as a compound of C_2H_4, ethylene, and H_2O, water, and oxalic acid (anhydrous), C_2O_3, as one of CO_2 with CO. The discovery of "isomeric compounds," i. e., of compounds which possess the same ultimate formula and yet differ entirely in their properties, forced upon chemists the necessity of attending to the structure of the molecule, for only by such a supposition could the difference between two isomeric bodies be explained. In 1823 Liebig discovered that silver fulminate and silver cyanate both possessed the empirical formula AgCNO. In 1825 this was followed by the discovery by Faraday that oil gas contains a hydrocarbon identical in composition with ethylene, C_2H_4, yet differing from it in properties; and in 1829 Wöhler, professor in Göttingen (1800–1882), discovered that urea, a constituent of urine, could be produced by heating ammonium cyanate, NH_4CNO, a substance of the same formula. It therefore became clear that the identity of a compound must depend on some other cause than its ultimate composition.

In 1833 Liebig and Wöhler took an important step in elucidating this question by their investigations on benzoic acid, an acid obtainable by distilling a resin named gum benzoin. They showed that this acid, $C_7H_6O_2$, could be conceived as consisting of the group C_7H_5O, to which they gave the name "benzoyl," in combination with OH; that benzoic aldehyde, C_7H_6O, might be regarded as its compound with hydrogen; that it also formed compounds with chlorine and bromine and sulphur, and replaced hydrogen in ammonia ($C_7H_6O.NH_2$). They termed this group benzoyl, a "compound element," or a "radical." This research was followed by one by Robert Bunsen, professor at Heidelberg, born in 1811, and recently (1899) dead, which bore reference to cacodyl, a compound of arsenic, carbon, and hydrogen, in which the idea of a radical was confirmed and amplified.

The idea of a radical having thus become established, Jean Baptiste Andrée Dumas, professor in Paris (1800–1884), propounded the theory of "substitution," i. e., that an element such as chlorine or oxygen (which, be it noticed, is electro-negative on Berzelius's scale) could replace hydrogen in carbon compounds, atom for atom, the resulting compound belonging to the same "type" as the one from which it was derived. And Laurent, warden of the mint at Paris (1807–1853), and Gerhardt, professor at Montpelier and at Strassburg (1816–1856), emphasized the fact that one element, be it what it may, can replace another without fundamentally altering its chemical character, and also that an atom of hydrogen can be replaced by a group of atoms, or radical, behaving for the occason like the atom of an element. It is to Laurent and Gerhardt that we owe the definition of an atom—the smallest quantity of an element which can be present in a compound; an equivalent—that weight of an element which combines with or replaces one part by weight of hydrogen; and a molecule—the smallest quantity which can exist in a free state, whether of an element or a compound. They recognized, too, that a molecule of hydrogen, chlorine, etc., consists of two atoms.

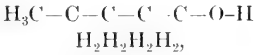
POWERS OF COMBINATION.

In 1849 Wurtz, professor in Paris (1817–1884), and Hofmann, then professor in the College of Chemistry in London, afterwards at Berlin (1818–1892), discovered series of compounds allied to ammonia, NH_3, in which one or more atoms of hydrogen were replaced by a group, or radical, such as methyl (CH_3), ethyl (C_2H_5), or phenyl (C_6H_5). Wurtz referred such compounds to the ammonia "type." They all resemble ammonia in their physical properties, smell, taste, etc., as well as in their power of uniting with acids to form salts resembling ammonium chloride (NH_4Cl) and other ammonium compounds. Shortly afterwards Williamson, professor at University College, London (1855–1887), added the "water type," in consequence of his researches on "mixed ethers"—bodies in which the hydrogen of water might be regarded as replaced by organic radicals. Thus we have the series, $H.O.H$; $CH_3O.H$; $CH_3.O.CH_3$; $NH_3NH_2.CH_3$; $NH\,(CH_3)_2$, and $N\,(CH_3)_3$, the first representing compounds following the water type, the latter the ammonia type. This suggestion had been previously made by Laurent in 1846. But Williamson extended his views to inorganic compounds; thus, sulphuric acid was represented as constructed on the double water type—$HO.SO_2.OH$, being derived from $H.O.(HH).O.H$, the two hydrogen atoms inclosed in brackets being replaced by the radical SO_2. To these types Gerhardt added the hydrogen and hydrogen chloride types, $H.H.$ and $H.Cl$; and later Kekulé, professor in Bonn (1829), added the marsh gas type CH_4. The next important step was taken by Frankland, professor in the Royal School of Mines, London. His work, however, had been anticipated by Crum Brown (professor at Edinburgh University) in a pamphlet even yet little known. It was to attribute to elements one or more powers of combination. To these he gave the name "valency," and the capacity of possessing valency was called "quantivalence." Thus hydrogen was taken as a "monad" or monovalent. Chlorine, because it unites with hydrogen atom to atom, is also a monad. Oxygen, having the power to combine with two atoms of hydrogen, was termed a dyad, or divalent; nitrogen a triad, or trivalent; carbon a tetrad, or tetravalent, and so on. This is evident from inspection of the formulæ of their compounds with hydrogen, thus:

Instances of penta-, hexa-, and even hepta-valency are not wanting.

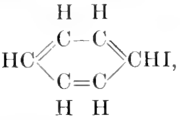
KEY TO STRUCTURE OF CHEMICAL COMPOUNDS.

This was the key to unlock the structure of chemical compounds; and Franklands' views, just stated, are still held by chemists. The determination of the constitution of compounds, chiefly those of carbon, occupied the attention of chemists almost exclusively until 1880. The plan of action is much the same as that of a mechanician who wishes to imitate a complicated mechanism. He must first dissect it into groups of mechanical contrivances; these are next constructed, and they are finally built together into the complete machine. In certain cases the atoms of carbon are arrranged in "chains," as, for example, in pentyl alcohol,

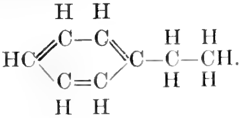


$$H_3C-\underset{H_2}{C}-\underset{H_2}{C}-\underset{H_2}{C}-\underset{H_2}{C}-O-H,$$

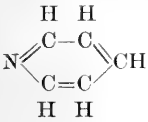
each atom being tetrad, and its "affinities," or powers of combination, saturated either with hydrogen or with those of neighboring atoms of carbon; in others they are in the form of a "ring," as in benzene, the formula of which was first suggested by Kekulé, viz:



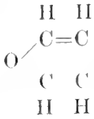
or in both, as in ethyl benzene.



One or more atoms of nitrogen, or of oxygen, may form part of the circle, as in pyridine,



and furfurane,

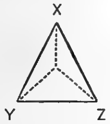


and so on. By means of conceptions such as these many interesting compounds have been built up out of the elements which they contain, e. g., urea and uric acid, constituents of urine; theobromine and caffeine, the essential principles of cocoa and tea; alizarine and indigo, valuable dyestuffs, and several of the alkaloids, bitter principles contained in plants, of great medicinal value.

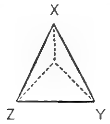
THE EFFECT ON INDUSTRIAL PROGRESS.

They have led, too, to the discovery of many brilliant colors, now almost universally employed, to the exclusion of those less brilliant, because less pure, derived from plants, and in one or two cases from animals; the manufacture of gun cotton, dynamite, and similar high explosives; and to the development of the candle industry, the sugar manufacture; to improvement in tanning, in brewing, and in the preparation of gas and oils for illuminating purposes. In short, it may be said that the industrial progress of the latter half of the century has been due to the theoretical views of which a short sketch has just been given.

Such formulæ, however, can evidently not represent the true constitution of matter, inasmuch as the atoms are imagined to lie on a plane, whereas it is evident that they must occupy space of three dimensions and possess the attributes of solidity. The conception which led to the formulation of such views was due first to Pasteur, in his later years director of the institute known by his name at Paris, and more directly to LeBel (Bulletin de la Société Chimique de Paris, 1874) and Van't Hoff (Voorstel tot Uitbreiding der Structuur-Formules in de Ruimte, 1874), now professor at Berlin, independently of each other. In 1848 Pasteur discovered that it was possible to separate the two varieties of tartaric acid from each other, and that that one which rotated the plane of polarized light to the right gave crystals with an extra face, unsymmetrically disposed with regard to the other faces of the crystal. The variety, the solution of which in water was capable of producing left-handed rotation, also possessed a similar face, but so placed that its reflection in a mirror reproduced the right-handed variety. Pasteur also showed that a mixture of these acids gave crystals not characterized by an unsymmetrically placed face, and also that the solution was without action on polarized light. These observations remained unexplained until LeBel and Van't Hoff, in 1874, simultaneously and independently devised a theory which has, up till now, stood the test of research. It is briefly this: Imagine two regular tetrahedra, or three-sided pyramids, standing each on its triangular base. An idea can best be got by a model, easily made by laying on a table three lucifer matches so as to form an equilateral triangle, and erecting a tripod with three other matches, so that each leg of the tripod stands on one corner of the triangle. At the center of such a tetrahedron an atom of carbon is supposed to be placed. Marsh gas, CH_4, is supposed to have such a structure, each corner, or solid angle of the structure (of which there are four), being occupied by an atom of hydrogen. This represents the solid or stereochemical formula of methane or marsh gas. Now, suppose one of the atoms of hydrogen in each of these structures to be replaced by chlorine, the group (OH), or any other monovalent element or group. It is evident that, if not exactly similar (owing to the replacement not having been made at similar corners in each), the two structures can be made similar by turning one of them round until the position of the substituting atom or group (which we will term X) coincides in position with X in the stationary one. If two such replacements be made, say with X and Y in each, coincidence can again be made to take place; but the same is not the case if X, Y, and Z replace the three atoms of hydrogen in the structure; for there is one way of replacement which is the optical image of the other and represents the other's reflection in a mirror,



and



DEVELOPMENT OF BACTERIOLOGY.

Now, it is found that when the four corners of such a structure are occupied by four separate atoms or groups, or when (as the expression goes) the body contains an "asymmetrical carbon atom," if the substance of one of its derivations can be obtained in a crystalline form, the crystals are also asymmetric, i. e., each develops a face which is the mirror reflection of a similar face developed on the other variety; and if a beam of polarized light be passed through the solution of the substance, its plane is rotated to the left if one variety be used, and, if the other, to the right. This hypothesis of LeBel's and Van't Hoff's has had an enormous influence on the progress of organic chemistry. By its means Fischer, now professor at Berlin, has explained the reason of the existence of the enormous number of bodies analogous to grape and cane sugar and has prepared many new varieties; and it appears likely that the terpenes, a class of bodies allied to turpentine, and comprising most of the substances to which the odor of flowers is due, may thereby find their explanation. It may be mentioned in passing that Pasteur, having found that ordinary mold destroyed one variety of tartaric acid rather than the other in a mixture of the two, and made use of this observation in order to prepare the unattacked variety in a state of purity, was led to study the action of organisms more or less resembling mold; and that this has led to the development of the science of bacteriology, which has had an enormous influence on our views regarding fermentation in general, and guides the work of our physicians, our surgeons (witness Lister's antiseptic treatment), our sanitary engineers in their estimate of the purity of drinking water and of the disposal of sewage, of our manufactures of beer and spirits, of wine growers, and more recently of farmers. All these processes depend upon the action of organisms in producing chemical changes, whether in the tissues of the body, causing or curing disease, or in the production of flavored alchohol from sugar, or in the manufacture of butter and cheese, or in preparing the land for the reception of crops. We also owe to the genius of Van't Hoff the most important advance of recent times in the region of physical chemistry. It had been observed by M. Raoult, professor at Grenoble, that the freezing point of a solvent as a general rule is lowered to the same extent if there be dissolved in it quantities of substances proportional to their molecular weights. Thus supposing 1.80 grams of grape sugar be dissolved in 100 grams of water and the solution cooled below 0° C. with constant stirring, ice separates suddenly in thin spicules, and the temperature rises to -0.185°. If 3.42 grams of cane sugar be similarly dissolved in 100 grams of water the freezing point of the solution is again -0.185°. Now 1.80 and 3.42 are respectively the hundredth part of the molecular weights of grape sugar ($C_6H_{12}O_6$) and cane sugar, $C_{12}H_{22}O_{11}$. Similarly, Raoult found that quantities proportional to molecular weights dissolved in a solvent depress the vapor pressure of that solvent equally, or, what comes to the same thing, raise its boiling point by an equal number of degrees. But ordinary salts, such as sodium chloride, potassium nitrate, etc., dissolved in water, give too great a depression of the freezing point and too high a boiling point. Next, it had been observed by botanists, De Vries, Pfeffer, and others, who had examined the ascent of sap in plants, that if a vessel of unglazed porcelain, so treated as to cause a film of cupric ferrocyanide (a slimy red compound) to deposit in the pores of its walls, be filled with a weak (about 1 per cent) solution of sugar or similar substance, and plunged in a vessel of pure water, water entered through the pores. By attaching a manometer to the porous vessel the pressure exerted by the entering water could be measured. Such pressure was termed "osmotic pressure," referring to the "osmosis," or passage through the walls of the vessel. Such prepared walls are permeable freely to water, but not to sugar or similar bodies. Van't Hoff pointed out that the total pressure registered is proportional to the amount of substance in solution and that it is proportional to the absolute temperature, and he showed, besides, that the pressure exerted by the sugar molecules is the same as that which would be exerted at the same temperature were an equal number of molecules of hydrogen to occupy the same volume as the sugar solution. This may be expressed by stating that when in dilute solution sugar molecules behave as if they were present in the gaseous state. Here again, however, it was noticed that salts tended to give a higher pressure; it was difficult to construct a semipermeable diaphragm, however, which would resist the passage of salt molecules, while allowing those of water to pass freely. Lastly, Arrhenius, of

Stockholm, had shown that the conductivity of salt solutions for electricity may be explained on the assumption that when a salt, such as KNO_3, is dissolved in water it dissociates into portions similar in number and kind to those it would yield if electrolyzed and if no secondary reactions were to take place. Such portions (K and NO_3 for example) had been named ions by Faraday. The conductivity of such solutions becomes greater, per unit of dissolved salt, the weaker the solution until finally a limit is reached, after which further dilution no longer increases conductivity. Now Van't Hoff united all these isolated observations and showed their bearing on each other. Stated shortly the hypothesis is as follows: When a substance is dissolved in a large quantity of a solvent its molecules are separated from each other to a distance comparable with that which obtains in gases. They are, therefore, capable of independent action and when placed in a vessel the walls of which are permeable to the solvent, but not to the dissolved substance ("semipermeable membrane"), the imprisoned molecules of the latter exert pressure on the interior surface of these walls as if they were gaseous. Van't Hoff showed the intimate connection between this phenomenon and the depression of freezing point and vapor pressure already alluded to. He pointed out further that the exceptions to this behavior, noticed in the case of dissolved salts, are due to their "electric dissociation" or "ionization," as it is now termed; and that in a sufficiently dilute solution of potassium nitrate, for example, the osmotic pressure and the correlated depression of freezing point and rise of boiling point are practically equal to what would be produced were the salt to be split into its ions, K and NO_3. These views were vigorously advocated by Ostwald (professor at Leipzig) in his "Zeitschrift für physikalische Chemie," and he and his pupils have done much to gather together facts in confirmation of this theory and in extending its scope.

It must be understood that the ions K and NO_3 are not, strictly speaking, atoms; they are charged atoms; the K retains a + and the NO_3 a − charge. On immersing into the solution the poles of a battery, one charged + and the other −, the +K atoms are attracted to the − pole and are there discharged; as soon as they lose their charge they are free to act on the water, when they liberate their equivalent of hydrogen. Similarly, the $-NO_3$ groups are discharged at the + pole and abstract hydrogen from the water, liberating an equivalent quantity of oxygen. Thus the phenomenon of electrolysis, so long a mysterious process, finds a simple explanation. The course of ordinary chemical reactions is also readily realized when viewed in the light of this theory. Take, for example, the ordinary equation:

$$AgNO_3.Aq+NaCl.Ag=AgCl+NaNO_3.Aq;$$

i. e., solutions of silver nitrate and sodium chloride give a precipitate of silver chloride, leaving sodium nitrate in solution. By the new views, such an equation must be written

$$\overset{+}{\mathrm{Ag}}.\mathrm{Aq}+\overset{-}{\mathrm{NO_3}}.\mathrm{Aq}+\overset{+}{\mathrm{Na}}.\mathrm{Aq}+\overset{-}{\mathrm{Cl}}.\ \mathrm{Aq}=\mathrm{AgCl}+\overset{+}{\mathrm{Na}}.\mathrm{Aq}+\overset{-}{\mathrm{NO_3}}.\mathrm{Aq}.$$

The compound, silver chloride, being insoluble in water, is formed by the union of the ions Ag and Cl and their consequent discharge, forming an electrically neutral compound; while the sodium ions, charged positively together with the NO_3 ions, negatively charged, remain in solution.

One more application of the principle may be given. Many observers, Andrews, Favre, and Silbermann, but especially Julius Thomsen, of Copenhagen, and M. Berthelot, of Paris, have devoted much labor and time to the measurement of the heat evolved during chemical reactions. Now, while very different amounts of heat are evolved when chlorine, bromine, or iodine combine, respectively, with sodium or potassium, the number of heat units evolved on neutralizing sodium or potassium hydroxide with hydrochloric, hydrobromic, hydriodic, or nitric acids is always about 13,500. How can this fact be explained? It finds its explanation as follows: These acids and bases are ionized in solution, as shown in the equation:

$$\overset{+}{\mathrm{H}}.\mathrm{Aq}+\overset{-}{\mathrm{Cl}}.\mathrm{Aq}+\overset{+}{\mathrm{Na}}.\mathrm{Aq}+\overset{-}{\mathrm{OH}}.\mathrm{Aq}=\mathrm{H.OH}+\overset{+}{\mathrm{Na}}.\mathrm{Aq}+\overset{-}{\mathrm{Cl}}.\mathrm{Aq}.$$

Water is the only compound formed, and it is produced by the union of the hydrogen ion originally belonging to the acid and the OH, or hydroxyl ion originally belonging to the base. No further change has occurred; hence the uniform evolution of heat by the interaction of equivalent quantities of these acids and bases.

PERIODIC ARRANGEMENT OF THE ELEMENTS.

It now remains to give a short account of the greatest generalization which has as yet been made in chemistry; it has been termed the periodic arrangement of the elements.

In 1864, Newlands, of London, and Lothar Meyer, late of Tübingen, found that by arranging the elements in the order of their atomic weights certain regularities were to be observed between each element, and in general the eighth in succession from it, in the order of their numerical value. Such similar elements formed groups or quantities, while the elements separating them belong to a period, hence the name "periodic arrangement." Commencing with lithium, a light, lustrous metal found as silicate in certain minerals, we have the following series.

Lithium	Beryllium	Boron	Carbon
7	9.2	11	12
Sodium	Magnesium	Aluminum	Silicon
23	24.3	27	28
Nitrogen	Oxygen	Fluorine	Neon
14	16	19	20
Phosphorus	Sulphur	Chlorine	Argon
31	32	35.5	40

and so on. It is only necessary to point out in detail the resemblances between the elements which stand in the vertical columns, but it may be stated that the resemblance extends also to the formulæ and properties of their compounds. Thus, the chlorides of lithium and sodium are each white, soluble salts of the formulæ LiCl and NaCl; oxides of magnesium and of beryllium are both insoluble, white, earthy powders, MgO and BeO (GeO), and so on. Newlands in his preliminary sketch, termed this order the "Law of Octaves," and predicted the existence of certain undiscovered elements which should occupy unfilled positions in the table. Mendeléef, professor at St. Petersburg, in 1869, amplified and extended these relations, and he and Meyer pointed out that the volume occupied by equal numbers of atoms of such elements underwent a periodic variation when the elements are classified as above. The prediction of undiscovered elements was made by Mendeléef in a more assured manner, and in several cases they have been realized. Thus, what Mendeléef called "ekaboron" has since been discovered by Lecoq de Boisbandron and named patriotically "Gallium." Mendeléef's "eka-silicon" is now known as "germanium," discovered by Winkler, and "eka-aluminum" is now Clève's "scandium." Moreover, the atomic weights of cæsium, beryllium, molybdenum, and mercury have been altered so that they fit the periodic table, and further research has justified the alteration.

The valency of these elements increases from right to left, as will be seen by inspection of the following series:

LiCl	$BeCl_2$	BCl_3	CCl_4	NH_4Cl	OH_2
Na_2O	MgO	B_2O_3	SiO_2	PC_3	SO_3
Monad.	Dyad.	Triad.	Tetrad.	Triad and Pentad.	Dyad and Hexad.

FH	Ne—
$Cl(OH)O_3$	A—
Monad and Heptad.	No valency.

The elements of no valency are of recent discovery. In 1894 Lord Rayleigh had determined the density of the nitrogen of the atmosphere, having separated from it the oxygen and carbon dioxide which are mixed with nitrogen in air. He found it to be of somewhat higher density than that obtainable from ammonia and other compounds of nitrogen. In conjunction with Ramsay he investigated atmospheric nitrogen; it was absorbed either by a method devised by Cavendish or by making it combine with magnesium at a red heat. They found that the unabsorbable residue possessed an unknown spectrum, and that its density was nearly 20. To this new gas they gave the name "argon," or inactive, seeing that all attempts to cause it to enter into combination had failed. In 1895 Ramsay, searching for possible combinations of argon in minerals, experimented with one which had been previously examined by Hillebrand, of Baltimore, and obtained from it helium, a gas of density 2, possessing a spectrum which had been previously discovered in 1868 in the chromosphere of the sun by Jannsen, of Paris, and named helium by Frankland and Lockyer. Subsequent liquefaction of crude argon by means of liquid air, prepared by a process invented simultaneously by Linde and Hampson, gave a residue which was named by its discoverers, Ramsay and Travers, "neon." Liquid argon has yielded two other gases also, "krypon" and "xenon." These elements form a separate group in the Periodic Table, commencing with helium, with atomic weight 4; neon, 20; argon, 40; krypon, 82, and xenon, 128. They all agree in being monoatomic; i. e., their molecules consist of single atoms, and they have no tendency to form compounds; i. e., they possess no valency.

CHEMISTRY AND COMMERCIAL SUPREMACY.

In this sketch of the progress of chemistry during the century which has just passed attention has been paid chiefly to the progress of thought. Allusions must, however, be made to the applications of chemistry to industrial purposes. The development of the soda industry, the preparation of carbonate of soda and caustic from common salt—initiated in France by Le Blanc (1742-1806)—has been developed by Tennant in Scotland, and Muspeath and Gossage, and by Hargreaves, Weldon, and Maetea in England. This process has at present a serious rival in the ammonia-soda process developed by Solway in Belgium and by Brunner and Mond in England. The manufacture of sulphuric acid, so long associated with the alkali process, has made enormous strides during the present century, but is still, in the main, the original process of causing sulphur dioxide in presence of water to absorb the oxygen of the air through nitric oxide. But the saving of the oxides of nitrogen through the invention of a sulphuric-acid tower by Gay-Lussac, known by his name, and the reutilization of these oxides in the "Glover" tower, invented by John Glover, of Newcastle, have greatly lessened the cost of the acid. Concentration of the acid in iron vessels is now common, the cost of platinum or of fragile glass vessels being thereby saved. The desulphurization of iron and the removal of silicon, carbon, and phosphorus by Bessemer's process, modified by Thomas and Gilchrist through the introduction of a "basic magnesia lining" for the converters, has made it possible to obtain pure iron and steel from ores previously regarded as of little value.

The use of artificial manures, prepared by mixing refuse animal matters with tetra-hydrogen, calcium phosphate, and nitrate of soda or sulphate of ammonia, first introduced by Liebig, has created a revolution in agricultural methods and in the weight of crops obtainable from a given area of soil. The influence of manures on crops has been fully studied by Lawes and Gilbert for more than fifty years in their experimental farms at Rothampstead. The most remarkable advances which have been made, however, are due to cheap electric current. The electrolysis of alumina, dissolved in fused cryolite to obtain aluminum, an operation carried out at Schaffhausen on the Rhine and at the Falls of Foyers in Scotland, the electro deposition of pure copper for electric wires and cables, electro silvering, gilding, and nickeling, all these are instances where decomposition of a compound by the electric current has led to important industrial results. At present soda and chlorine are being manufactured by the electrolysis of salt solution contained in rocking trays, one of the electrodes being mercury, by the Castner-Kellner process. This manufacture is being carried on at Niagara, as well as in England. But electricity as a heating agent finds ever-extending application. Henri Moissan (professor at Paris) led the way by utilizing the enormous heat of the arc in his electric furnace, thereby, among other interesting reactions, manufacturing diamonds, small, it is true, though none the less real. The use of electricity as a heating agent has received new applications. Phosphorus is now made by distilling a mixture of phosphates of lime and alumina with coke; a new polishing agent has been found in "carborundum," a compound of carbon and silicon produced by heating in an electrical furnace a mixture of sand and coke, and cyanide of potassium, almost indispensable for the extraction of gold from ores poor in gold, is now manufactured by heating a mixture of carbon and carbonate of barium in an electric furnace in a current of carbon monoxide. These are but some of the instances in which electricity has been adopted as an agent in effecting chemical changes, and it may be confidently predicted that the earlier years of the twentieth century will witness a great development in this direction. It may be pointed out that the later developments of industrial chemistry owe their success entirely to the growth of chemical theory; and it is obvious that that nation which possesses the most competent chemists, theoretical and practical, is destined to succeed in the competition with other nations for commercial supremacy and all its concomitant advantages.

LIQUID HYDROGEN.[1]

By Professor Dewar, M. A., LL. D., F. R. S., M. R. I.

My colleague, Lord Rayleigh, in his commemoration lecture dealt so admirably and exhaustively with some of the discoveries of our great predecessors in this institution that it will be unnecessary to pursue further the lines of historical treatment in this lecture. Instead of discoursing generally on the chemical side of the work of Davy and Faraday and their successors, it has seemed to me more appropriate to attempt some experimental demonstrations of the latest modern developments in a field of inquiry opened out to science by the labors of the two illustrious chemists just mentioned. With this object in view, my discourse this evening will be confined to the subject of liquid hydrogen. Davy said: "Nothing tends so much to the advancement of knowledge as the application of a new instrument. The native intellectual powers of man in different times are not so much the causes of the different success of their labors as the peculiar nature of the means and artificial resources in their possession." The new instrument of research, which for the first time we have to experiment with before an audience, is the liquid form of the old inflammable air of Cavendish. Lavoisier toward the end of the last century had the scientific acumen to declare that, in his opinion, "if the earth were suddenly transported into a very cold region, the air, or at least some of the aeriform fluids which now compose the mass of our atmosphere, would doubtless lose their elasticity for want of a sufficient temperature to retain them in that state. They would return to the liquid state of existence and new liquids would be formed, of whose properties we can not at present form the most distant idea." Black, about the same time, in discussing the properties of hydrogen, makes the following suggestive observations: "We may now further remark, with regard to inflammable air, that it is at present considered as one of the simple or elementary bodies in nature. I mean, however, the basis of it, called the hydrogen by the French chemists; for the inflammable air itself, namely, hydrogen gas, is considered as a compound of

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[1] Centenary commemoration lecture, Royal Institution of Great Britain, Wednesday, June 7, 1899, His Grace the Duke of Northumberland, K. G., president, in the chair, by Professor Dewar, M. A., LL. D., F. R. S., M. R. I., Fullerian professor of chemistry R. I.

that basis and the matter of heat. What appearance and properties that basis would have, were it deprived of its latent heat and elastic form, and quite separated from all other matter, we can not tell." The accuracy of the prophecy of Lavoisier has been experimentally verified, but until recently we had no distinctive answer to the riddle of Black. The object of this lecture will be an attempt to advance the solution of the problem suggested by Black a century ago. It is interesting to note how confident Faraday was that hydrogen would ultimately be obtained in the liquid and solid form. In the course of one of his lectures delivered in the year 1852 he said: "There is reason to believe we should derive much information as to the intimate nature of these nonmetallic elements if we could succeed in obtaining hydrogen and nitrogen in the liquid or solid form. Many gases have been liquefied; one, carbonic-acid gas, has been solidified; but hydrogen and nitrogen have resisted all our efforts of this kind. Hydrogen, in many of its relations, acts as though it were a metal; could it be obtained in a liquid or solid condition the doubt might be settled. This great problem, however, has yet to be solved; nor should we look with hopelessness on this solution, when we reflect with wonder—and, as I do, almost with fear and trembling—on the powers of investigating the hidden qualities of these elements, of questioning them, making them disclose their secrets and tell their tales, given by the Almighty to man." It must be confessed, however, that later physicists and chemists were almost forced to conclude that the problem was a hopeless one. The full history of the liquefaction of hydrogen has been dealt with in a Friday evening discourse[1] delivered in January of this year, so that all questions dealing with the work of other investigators may for the present be omitted in order to save time for the experimental illustrations.

This large spherical double-walled and silvered vacuum vessel contains 1 liter of liquid hydrogen. You observe it is lifted out of a large cylindrical vessel full of liquid air. In order to diminish the rate of evaporation it is necessary to surround the vessel in which the hydrogen is collected with liquid air. Under such conditions the rapidity of evaporation is about the same as that of liquid air when kept in a similar vessel in the ordinary way. In order to prove that hydrogen is present in the liquid form, the simplest experiment is to remove the cotton-wool plug, which takes the place of a cork, and insert a metallic wire, to the end of which is attached a ball of asbestus for the purpose of absorbing the liquid. On bringing it quickly into the air and applying a light it burns with the characteristic appearance of the hydrogen flame (Fig. C, Pl. II). The liquid can readily be poured from one variety of vacuum vessel into another, so that by means of this unsilvered cylindrical form the appearance of the liquid and other experiments may be projected on

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[1] Reprinted in Smithsonian Report, 1899, pages 131–142.

a screen (Fig. A, Pl. II). The liquid hydrogen appears in gentle ebullition and is perfectly clear, only there is a white solid deposit in the bottom of the tube, which is really solid air. This may be shown by removing for an instant the cotton-wool stopper, when you see a snow of solid air falling in the liquid. It is easy to arrange a method of carrying liquid hydrogen in a small vacuum vessel in such a way as to prevent the access of air. This is shown in fig. 1, Pl. I, where the vacuum vessel, after it has been filled by dipping it into the main supply by means of a supporting wire, is surrounded with a glass envelope, which becomes filled with an atmosphere of hydrogen gas constantly maintained, thereby preventing the access of air. That the density of the liquid is very small and is altogether unlike liquid air is shown by dropping small pieces of cork, which float readily in the latter liquid but sink instantly in the hydrogen (Fig. B, Pl. II). The real density of the liquid is only one-fourteenth that of water, so that it is by far the lightest known liquid. This small density explains the rapidity with which the liquid is cleared on the entrance of the air snow. The relative smallness of the gas bubbles produced in the actively boiling liquid, which causes an appearance of opalescence, is really due to the small surface tension of the liquid hydrogen. The coefficient of expansion of liquid hydrogen is some five times greater than that of liquid oxygen, and is comparable with that of carbonic acid, about 5° from its critical point. The latent heat of evaporation is about 190 units, and the specific heat of the liquid is very high, and, so far as my experiments go, leads me to the value 6. This is in very marked contrast to the spectic heat of liquid oxygen, which is about 0.5. The extraordinary lowness of its boiling point is at once apparent by cooling a piece of metal in the liquid and then removing it into the air, when it will be seen to condense for a moment solid air on its surface which soon melts and falls as a liquid air. This may be collected in a small cup, and the production of oxygen demonstrated by the ignition of a red-hot splinter of wood after the chief portion of the nitrogen has evaporated. If a long piece of quill tubing sealed at one end, but open at the other, is placed in the liquid, then the part that is cooled rapidly fills with liquid air. On stopping any further entrance of air by closing the end of the tube, the liquid air quickly becomes solid, showing in the interior a hollow spindle from contraction, in passing from the liquid into the solid form (Fig. E, Pl. II). On bringing the tube containing the solid from the liquid hydrogen bath into the air we observe liquid air running from the surface while the solid air inside is seen to melt (Fig. D, Pl. II). Here is a tube into which liquid oxygen has been poured. On placing it in liquid hydrogen it freezes to a clear blue ice. Liquid nitrogen under similar circumstances forms a colorless ice. If instead of an open tube in free air we employ a closed vessel of about a liter capacity to which the quill tube is attached, then, on repeating the experiment, the same results follow, only the volume of the liquid air formed agrees with the total quantity present in the vessel. This suggests that any air left in the closed vessel must have a very small pressure. This is confirmed by attaching a mercurial gauge to any vessel containing air, when it will be seen the vacuum produced by hydrogen cooling is equal to that of a Torricellian vacuum (fig. 2, Pl. I). To reach such a high exhaustion the solid oxygen and nitrogen at the boiling point of hydrogen must be practically nonvolatile or have an exceedingly small vapor pressure. If the ordinary air contains free hydrogen, helium, etc., which are noncondensable in this way of working, then the vacuum would not be so high as with pure oxygen or nitrogen. This method may be used to separate the incondensable gases from the air. Such air vacua when examined spectroscopically show the lines of hydrogen, helium, and neon. We may now employ this process to produce high vacua, and test their exhaustion by the character of the electric discharge. Vacuum tubes which have been prepared in this way show extraordinary resistance to the passage of the electric discharge; they also show the marked phosphorescence of the glass characteristic of Crookes tubes (Figs. F and G, Pl. II). It is, however, the rapidity with which such high exhaustions can be attained that is so interesting. You will observe that this large Geissler tube, previously exhausted to some 3 inches pressure, will, when the end part is immersed in liquid hydrogen, pass through all the well-known changes in the phases of striation—the glow on the poles, the phosphorescence of the glass—in the space of a fraction of a minute. From this it follows that theoretically we need not exhaust the air out of our double-walled vessel when liquid hydrogen has to be stored or collected. This makes a striking contrast to the behavoir of liquid air under similar circumstances. The rapid exhaustion caused by the solidification of the air on the surface of a double-walled unexhausted test tube, when liquid hydrogen is placed in it, may be shown in another way. Leave a little mercury in the vessel containing air, just as if it had been left from making a mercurial vacuum. Now, we know mercury, in such a vacuum, can easily be made to distill at the ordinary temperature when we cool a part of the vessel with liquid air, so that we should expect the mercury in the unexhausted test tube to distill on to the surface cooled with the liquid hydrogen. This actually takes place. A rough comparison of the relative temperatures of boiling hydrogen and oxygen may be made by placing two nearly identical hydrogen-gas thermometers operating at constant pressure side by side and cooling each with one of the liquids (Pl. III). It will be seen that the contraction in the thermometer cooled with liquid hydrogen elevates the liquid some six times higher than that of the corresponding liquid column of the thermometer placed in the liquid oxygen. A constant-volume hydrogen thermometer constructed as shown in Pl. IV gave the boiling point of 21° absolute or −252° C., and a similar helium thermometer gave the same result. The critical temperature is about 32° absolute or −241° C., and the critical pressure about 15 atmospheres. If a closed vessel is full of hydrogen gas at atmospheric pressure, then, unlike the air vessels, it shows no condensation when a part of it is cooled in liquid hydrogen. To produce liquefaction we must increase the pressure of the gas or reduce the boiling point of the liquid hydrogen by exhaustion. Pure hydrogen liquefied in a closed vessel is perfectly clear, showing no trace of color or any appearance of absorption bands in the position of the spectrum lines. Electric sparks passing in the liquid when examined with the spectroscope show the ordinary line spectrum without any reversals. The vapor of boiling hydrogen is about fifteen times denser than that of the ordinary gas, thus bringing it up to the density of air. The liquid hydrogen, at its boiling point, is about sixty times denser than the vapor coming off. In the case of oxygen the density of the liquid is 255 times that of the vapor at its boiling point.

If a piece of cotton wool in the form of a little ball is attached to a thread, placed in liquid hydrogen, and then brought into the magnetic field, it is found to be strongly magnetic. This is simply due to the condensation of solid and liquid air in the pores of the wool. This substance we know is magnetic on account of the oxygen it contains. Pure liquid hydrogen is not magnetic, but when the solid air snow is in suspension in the fluid, then the magnetic character of the latter becomes apparent when the vessel is placed in the magnetic field.

All the phosphorescent effects produced at low temperatures formerly described are intensified at the much lower temperature of boiling hydrogen. To stimulate phosphorescence at the temperature of liquid air, ultraviolet light had to be employed, and then the solid body, organic or inorganic, allowed to rise in temperature. It was during the rise of temperature that the marked luminous emission took place. Amongst inorganic bodies the platino-cyanide of ammonia is very remarkable in this respect, and generally the group in organic chemistry known as the ketonic bodies. In the case of bodies cooled in liquid hydrogen, it appears that some show phosphorescence by simple stimulation with the light coming from an ordinary carbon filament electric lamp. The light in this case coming through glass contains only, we may say, the visible spectra, so that the ultraviolet rays are not now essential. It is strange to find photographic action still relatively considerable. At the boiling point of liquid air the photographic intensity is reduced by 80 per cent of the value at the ordinary temperature. The photographic effect on a sensitive film immersed in liquid hydrogen as compared with the same placed in liquid air is as 1 to 2, so that 10 per cent of the action at ordinary temperatures still remains. As every kind of chemical action so far examined is nonexistent at this extreme temperature, these experiments suggest that the cause of the photographic action may be essentially physical. No better illustration could be given of the rapid diminution of chemical action at low temperatures than to remind you that fluorine gas, the most active elementary body, under such conditions may be liquefied and kept in glass vessels.

The effect of a temperature of 21° absolute on the electric resistance of the pure metals is a problem of great interest. In passing from the melting point of ice to the boiling point of hydrogen, pure platinum loses resistance till only one-fortieth remains, and in the case of electrolytic copper the remaining resistance is only one fifty-seventh of what it was at starting. Such results suggest the approach to the condition of what may be called relatively perfect electric conductivity as the zero of absolute temperature is approached.

Liquid hydrogen is a nonconductor of electricity, and as regards being an insulator for currents of high potential it is comparable to that of liquid air. The properties of the liquid we have witnessed in no way suggest the metallic character that chemists like Faraday, Dumas, and Graham anticipated; and for the future hydrogen must be classed with the nonmetallic elements.

The liquefaction of hydrogen has been the consequence of some ten years' devotion to low-temperature research. To many it may seem that the results have been indeed costly in more ways than one. The scientific worker who prepares the way for future development in this sort of inquiry generally selects complicated methods, and is attracted or diverted into many bypaths of investigation. He may leave to his successors any credit that may be attached to cheapness and ease of production of the agent of research—results that must invariably follow. Liquid hydrogen is an agent of research which will enable us to examine into the properties of matter at the lowest-maintained temperature ever reached by man. Much work has still to be accomplished. One of the most fascinating problems of the study of low temperatures has been materially advanced. The interval separating us from the zero of absolute temperature has been reduced to practically one-fourth the value that it stood at when liquid air was the cooling agent. We can produce in pure Helium instantaneous temperatures, bringing us still nearer the goal. Now we can maintain a temperature within less than 16° of this zero, and the investigator who will make the further attempt to reduce this distance by an equivalent amount, thereby reaching a steady temperature of 4° or 5° absolute, will indeed face a problem of almost insuperable difficulty. Well, let us take comfort in an aphorism of Davy's: "Fortunately for the active and progressive nature of the human mind, even experimental research is only a method of approximation to truth."

The success of the demonstration has been largely due to the unremitting exertions of my chief assistant, Mr. Robert Lennox, and to the valuable aid given by Mr. J. W. Heath.

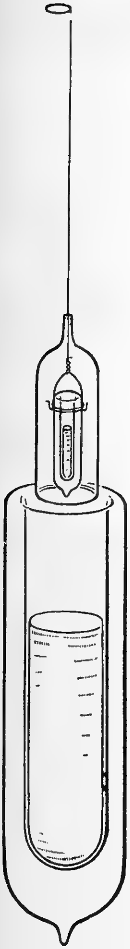


Fig. 1.

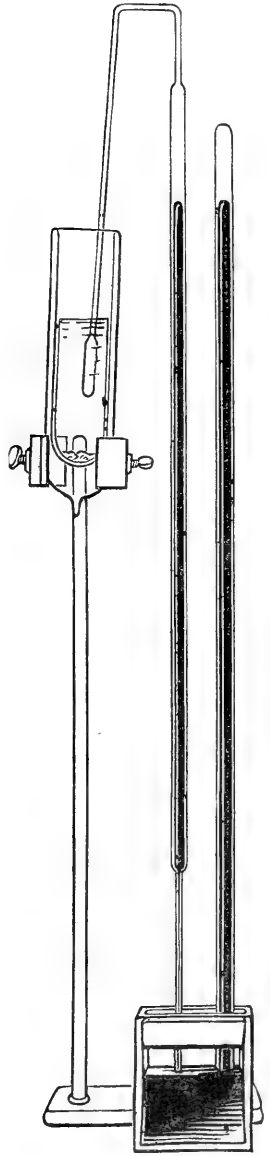
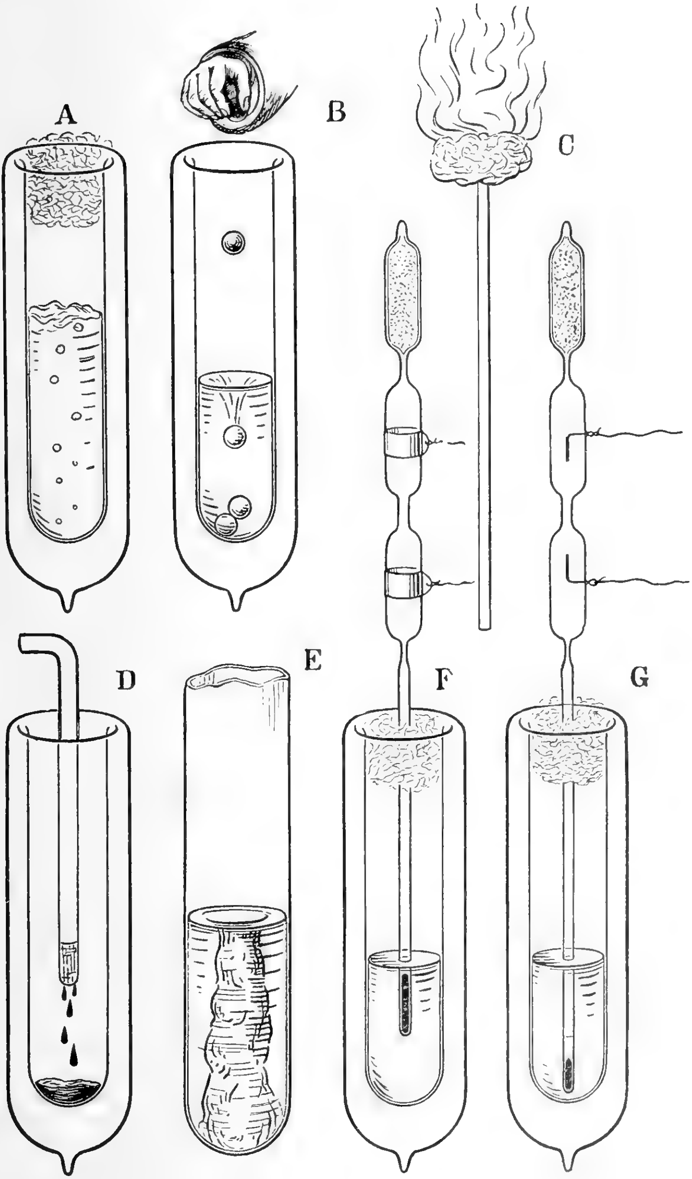


Fig. 2.

LIQUID HYDROGEN EXPERIMENTS.



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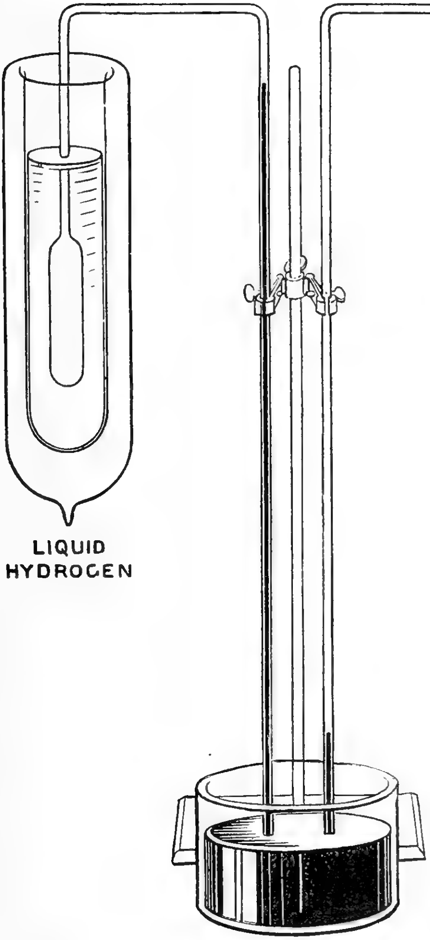

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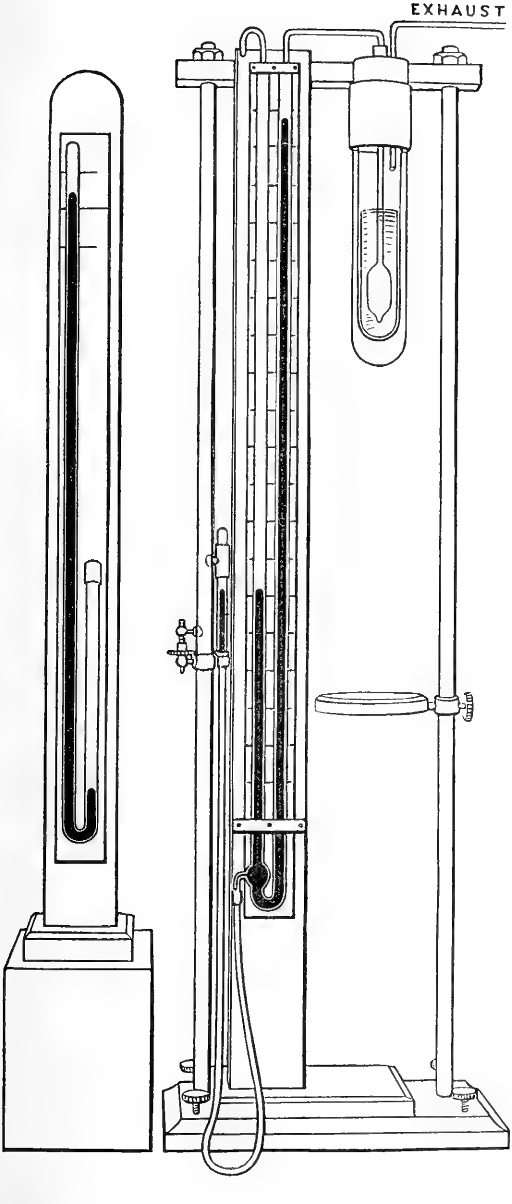

LIQUID HYDROGEN EXPERIMENTS.

A CENTURY OF GEOLOGY.[1]

By Prof. JOSEPH LE CONTE.[2]

Geology is one of the youngest of the sciences. It may almost be said to have been born of the present century. It is true that knowledge concerning the structure of the earth had been accumulating ever since the time of the Greeks and Romans; it is true that these materials became more abundant and were better organized in the eighteenth century; but this knowledge had not yet taken form as a distinct branch of science until about the end of that century. There are two distinctive marks of scientific as compared with popular knowledge: First, that its fundamental idea is clearly conceived; and, second, that its method is distinctly inductive.

1. *Fundamental idea.*—The fundamental idea underlying geological thought is the history of the earth. Now, until the beginning of the present century the earth was not supposed to have any history. It was supposed to have been made at once, out of hand, about six thousand years ago, and to have remained substantially unchanged ever since as the necessary theater of human history. Changes were known to have taken place, and in less degree to be still taking place, but these were not supposed to follow any law such as is necessary to constitute a history, and thus to constitute a science distinct from geography. Buffon, about the middle of the last century, did indeed bring out dimly the idea of an abyss of time, preceding the advent of man, in which the earth was inhabited by animals and plants wholly different from those of the present day, but he was compelled by the priests of the Sorbonne to retract these supposed irreligious views. So tardily was the fundamental idea of geology clearly conceived that Comte, the great originator of scientific philosophy, in his classification of the sciences in 1820, denied a place to geology because, according to him, it was not a distinct science at all, but only a field for the application of all the sciences. It is evident that he did not perceive the fundamental

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[1] Reprinted, by permission, from Appleton's Popular Science Monthly, Vol. LVI, February and March, 1900.

[2] In this article I have attempted to give only the development of geological thought.

idea underlying geology and distinguishing it from geography, viz, a life history of the earth through all time. The claim of geology to a place in a scheme of classification is exactly the same as that of astronomy. As astronomy is a field for the application of mathematics, mechanics, physics, and, recently, chemistry, but is distinguished from them all by its characteristic fundamental idea of illimitable space, so geology is a field for the application of all other lower sciences, but is distinguished from them all by her characteristic, fundamental idea of illimitable time. As all other sciences are terrestrial, but astronomy alone celestial, so all other sciences belong to the present—the "now"—but geology alone belongs to the illimitable past. The fundamental idea of the one is infinite space, of the other infinite, in sense of inconceivable, time. All other sciences, including astronomy, are but a flash-light view of Nature. Geology alone is a view of Nature in continuous movement—a life history—an evolution of Nature. This mode of thought began to dawn only in the closing years of the last and the opening years of the present century. It seems to have been first clearly conceived by the mind of Hutton in the last part of the eighteenth century.

2. *Inductive method applied.*—When the true idea underlying geology was clearly conceived, and geology thus distinctly separated from other departments of science, geology may be said to have been born. But it was still in helpless infancy, its growth irregular, and even its continuous life uncertain, because a solid basis of inductive method was not yet laid. That basis was laid mainly by Hutton in 1795[1] and still more clearly by Charles Lyell in 1830, in the principle that the study of causes now in operation is the only true foundation of geology.

Geological changes, of course, belong to the irrevocable past, and are therefore hopelessly removed from direct observation. Their causes and process must be reconstructed by the skillful use of the scientific imagination. Until Lyell, more or less probable hypotheses seemed all that was possible. What a field was here for the conflict of opposite extreme views! But Lyell showed that "causes now in operation" are producing similar effects under our eyes, if we will only observe. From that moment geology became a truly inductive science and its indefinite progress assured.

These two events, then, viz, the conception of geology as a distinct science and the introduction of a true scientific method, are the greatest epochs in the history of geological science. Some dim adumbrations of these appear before this century, especially the former in the mind of Buffon, and the latter somewhat fully in the mind of Hutton, but they were not generally accepted and had not become working principles until the beginning and even some time after the beginning

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[1] Hutton's Theory of the Earth.

of the nineteenth century. These must be borne in mind in all we have further to say of the progress of geology through the century.

When the century opened, the war between the Neptunists and the Plutonists, between the Wernerites and the Huttonites, was still going on, but was approaching the usual result in such cases of dispute, viz, the recognition of the fact that there was truth on both sides, and they must be combined into a more comprehensive view. The chief difference of opinion still remaining was as to the relative importance of the two agencies, aqueous and igneous. Two great advances took place about the beginning of this century. William Smith, by patient, painstaking field observation and mapping, laid the foundation of stratigraphy; and Cuvier, by his profound and brilliant studies of the wonderful discoveries of extinct mammals in the Eocene basin of Paris, laid the foundations of paleontology. These researches placed in clearer light than ever before the existence of other time-worlds before the present one. William Smith published his tabular view of the British Strata in 1790, but his map was not completed and published until 1815. Cuvier's great work on the Organic Remains of the Paris Basin was published in 1808.

Thus, early in the century the two bases of our science were laid by Smith and Cuvier. We now proceed to touch lightly only the main steps of subsequent growth through the century.

As, in the previous century and the early part of this, the discussion was between the opposite schools of Neptunists and Plutonists, with the final result of reconciliation in a more scientific view which combined these two surface views into a stereoscopic reality, so now the discussions began between catastrophism and uniformitarianism, and ended with a similar final result. Geologists, in the early part of the century, before the study of causes and processes now in operation was generally acknowledged as the only rational basis of a true scientific geology, seeing the frequent unconformities in the geological series and the apparently sudden changes of life forms associated with these unconformities, were naturally led to the conclusion that the whole history of the earth consisted of a series of sudden and violent catastrophes by which the bed of the ocean was suddenly raised and its waters precipitated on the land as a great wave of translation, carrying universal ruin and extermination of all life in its course. Such catastrophes were supposed to be followed by periods of quiet, during which the new earth was repeopled, by direct act of creation, with new forms of life adapted to the new conditions.

This view was in perfect accord with the then accepted doctrine of the supernatural origin and the permanence of species. Species were supposed to have been created at once, out of hand, without natural process, in some place (center of specific origin), spread in all directions as far as physical conditions would allow, but remained unchanged and unchangeable as long as they continued to live or until another universal exterminating catastrophe. Species are "medals of creation." They are successive individuals struck from the same die, until the die is worn out or broken. Then a new die is made, and the process of coinage of identical individuals is renewed.

Thus the whole history of the earth was supposed to consist of a succession of alternate supernatural and natural events. The catastrophes were supernatural; the times of quiet were natural. The creation of new dies or creation of first individuals was supernatural; the coinage of individuals of successive generations was natural. But on the whole the successive conditions of physical geography and the successive faunas and floras were higher and more complex according to a preordained plan. The great apostles of catastrophism were Cuvier in France and Buckland in England. According to Buckland, the last of these great catastrophes was the Quaternary or drift period, and this period was, by him and by many others since, associated with the Noachian Deluge.

Lyell opposed this view with all his power. According to him we can not judge of geological causes and processes except by study of causes and processes now in operation and producing effects under our eyes. The slow operation of similar causes and processes is sufficient—given time enough—to account for all the phenomena in geological history. Thus arose the extreme opposite doctrine of uniformitarianism. Things have gone on from the beginning and throughout all time much as they are going on now. This view, of course, required illimitable time, and was of great service in enforcing this idea. But, in revulsion from the previous idea of catastrophism, it undoubtedly was pushed much too far.

Meanwhile the theory of evolution was incubating in the mind of Darwin. Even Lyell, while he established the doctrine of slow uniform changes so far as inorganic nature was concerned, was still compelled to admit supernatural catastrophic changes in organic nature. Species, even for Lyell, were still immutable—still there were supernatural creation of first individuals, and continuance of similar individuals by natural process of generation. On the publication of Darwin's Origin of Species by Descent with Modification, Lyell at once embraced the new view as a completion of his principle of causes now in operation and his doctrine of uniformitarianism. In a certain superficial sense evolution is certainly confirmatory of the doctrine of uniformity of causes and processes in the past and the present, but in a deeper sense it is quite contrary in its spirit. Uniformitarians of the Lyell school look upon geology as a chronicle of events—evolutionists as a life history of the earth. The one regards the slow changes as irregular, uncertain, without progress or purpose or goal; the other as an evolution to higher and higher conditions, as a gradual movement onward toward the present condition and toward man as its goal. The recognition of this is only now approaching clearness. If geology is the history of the evolution of the earth from primal chaos until now, then the conditions have changed at every step, and absolute uniformity is impossible. Extreme uniformitarianism is therefore untenable. Catastrophism and uniformitarianism are opposite extremes which must be combined and reconciled. This reconciliation is only now being completed, and we therefore put off its discussion for the present. Suffice it to say now that geologic thought in this regard has passed through three stages—catastrophism, uniformitarianism, and evolutionism. And this latter is the final stage, because (1) it is a complete reconciliation between the other two, and (2) because it is plastic and indefinitely modifiable and progressive, while the other two are equally rigid and unchangeable by their mutual antagonism.

With these fundamental principles in mind, we proceed to touch briefly the most important advances during the century.

EVOLUTION OF EARTH FORMS.

The idea of the progressive development of the earth in its greater features throughout all geologic time by the action of forces resident in the earth itself preceded the acceptance of the evolution of organic forms. We have said that the fundamental idea of geology is that of the evolution of the earth through all time. Now, it was Dana who first studied geology wholly from this point of view. For him geology was the development of the earth as a unit. Before him, doubtless, geology was a kind of history—i. e., a chronicle of thrilling events—but Dana first made it a philosophic history. Before Dana, geology was an account of the succession of formations and their fossil contents. Dana made it an account of the evolution of earth forms and the concomitant and resulting evolution of organic forms. It is true that first and for a long time his evolutional conception was incomplete. It is true that while he attributed the evolution of earth forms to natural causes and processes, he still shrank from applying similar causes to the changes in life forms, but this was the almost necessary result of the then universal belief in the supernatural origin and the unchangeableness of organic forms. He lived to make his conception of evolution as a natural process, both of the earth and of organic forms, complete.

Ocean basins and continents.—If we divide geological causes and processes into two general kinds as to their origin—viz. internal or earth-derived, and external or sun-derived—evidently the former is the original and fundamental kind. These determine earth forms, while the other only modify them; these determine the great features, the other only the lesser features; the former rough-hews the earth features, the latter shapes them. It is the effects of these interior earth forces which are the most important to study. And among these effects the most fundamentally important of all is the formation of those greatest features—the ocean basins and continental arches. The most probable view is that they are formed by unequal radial contraction in the secular cooling of the earth. The earth was certainly at one time an incandescently hot mass, which gradually cooled and contracted to its present temperature and size. Now, if it were perfectly homogeneous both in density and in conductivity in all parts, then, cooling and contracting equally in every part, it would retain its symmetric oblate-spheroid form, though diminishing in size. But if there were any, the least, heterogeneity either in density or especially in conductivity over large areas, then the more conductive areas, contracting more rapidly toward the center radially, would form hollows or basins, and the less conductive areas would stand out as higher arches. Thus were formed the oceanic basin and the continental arches of the lithosphere. The same causes which produced would continue to increase them, and thus the ocean basins would increase in depth and the continents in height.

The hydrosphere is still to be added. In the beginning of this process doubtless the lithosphere was hot enough to maintain all the water in the form of vapor in the atmosphere. But when the surface was cool enough the water would precipitate and partly or wholly cover the earth—whether partly or wholly would depend on the amount of precipitated water and the amount of inequality which had already taken place. The amount of water, as we know, is sufficient, if the inequalities were removed, to cover the whole surface 2½ miles deep. Inasmuch as the forming of the inequalities is progressive, and still going on, it seems improbable that the inequalities had become sufficiently great, at the time of precipitation, to hold the waters. If this be so, then the primeval ocean was universal and the future continents existed only as continental banks in the universal ocean.

However this may have been, there seems little doubt that the same cause which produced the inequalities continued to operate to increase them. The ocean basins, so far as these causes are concerned, must have become deeper and deeper, and the continents larger and larger. In spite of many oscillations producing changes mostly on the margins, but sometimes extending over wide areas in the interior of the continent, this, on the whole, seems to be in accordance with the known geological history of the earth. If so, then the oceanic basins have always been oceanic basins, and the places of the continents have always been substantially the same. This introduces a subject on which there has been much discussion recently, viz:

The permanency of ocean basins.—Closely associated with the Lyellian uniformitarianism was the doctrine of extreme instability of earth features, especially the forms and places of sea and land. Crust movements were irregularly oscillating to such a degree that in the course of geologic history sea and land frequently and completely changed places. Abundant evidence of this was supposed to be found in the unconformities so frequent in the stratified series. The tendency of that time was toward a belief in up-and-down movements, back-and-forth changes, without discoverable law rather than progressive onward movement. On first thought it might seem that such lawless movement was rather in keeping with catastrophism than uniformitarianism. But not so, for the movements are supposed to be very slow. Again, it might seem on first thought that gradual progressive change—in a word, evolution—would be peculiarly in accord with uniformitarian ideas. But again not so, because this doctrine was, above all, a revulsion from the idea of supernatural purpose or design or goal contained in catastrophism. Uniformitarianism strongly inclined toward purposelessness, because of its supposed identity with naturalism. Thus for a long time, and still with many geologists, the tendency is toward a belief in irregular movements without discoverable law—toward instability of even the greatest features of the earth, viz, sea basins and continental arches. Geology for them is a chronicle, not a life history.

The contrary movement of thought may be said to have commenced with Dana. Dana studied the earth as a unit, as in some sense an organism developing by forces within itself. The history of the earth is a life history moving progressively toward its completion. The forces originating oceanic basins and continental arches still continue to deepen the former and enlarge the latter. From this point of view oceanic basins and continental arches must have always been substantially in the same places. Oscillations there have been at all times and at all places, but they affect mainly the outlines of these great features, though sometimes affecting also the interior of continents and mid-sea bottoms, but not sufficiently to change greatly their general form, much less to interchange their places.

Such is the doctrine of permanency of oceanic basins. It is undoubtedly a true doctrine, but must not be held in the rigid form characteristic of early thought. The forces originating oceanic basins still continue to deepen them and to increase the size and height of continents, but other forces are at work, some antagonizing (i. e., cutting down the continents and filling up the ocean beds), and still others determined by causes we little understand, by oscillations over wide areas, greatly modifying and often obscuring the effects of the basin-making movements. Here, then, we have two kinds of crust movements: The one fundamental and original, determining the greatest features of the earth and moving steadily onward in the same direction, ever increasing the features which it originates; the other apparently lawless, uncertain, oscillating over very wide areas, modifying and often obscuring the effects of the former. The old uniformitarians saw only the effects of the latter, because these are most conspicuous. The new evolutionists add also the former and show its more fundamental character, and thus introduce law and order into the previous chaos. The former is the one movement which runs ever in the same direction through all geologic time. The latter are the most common and conspicuous now and in all previous geologic time. The former underlies and conditions and unifies the history; the latter has practically determined all the details of the drama enacted here on the surface of the earth. Of the causes of the former we know something, though yet imperfectly. Of the causes of the latter we yet know absolutely nothing. We have not even begun to speculate profitably on the subject, and hence the apparent lawlessness of the phenomena. A fruitful theory of these must be left to the coming century.

Mountain ranges.--If oceanic basins and continental domes constitute the greatest features of the earth's face, and are determined by the most fundamental movements of the crust, surely next in importance come great mountain ranges. These are the glory of our earth, the culminating points of scenic beauty and grandeur. But they are so only because they are also the culminating points, the theaters of greatest activity, of all geological forces, both igneous and aqueous—igneous in their formation and aqueous both in the preparatory sedimentation and in the final erosive sculpturing into forms of beauty. A theory of mountain ranges, therefore, lies at the bases of all theoretical geology. To the pre-geologic mind mountains are the type of permanence and stability. We still speak metaphorically of the everlasting hills. But the first lesson taught by geology is that nothing is permanent; everything is subject to continuous change by a process of evolution. Mountains are no exception. We know them in embryo in the womb of the ocean. We know the date of their birth; we trace their growth, their maturity, their decay, their death; we even find in the folded structure of the rock, as it were, the fossil bones of extinct mountains. In a word, we are able now to trace the whole life history of mountains.

Mountains, therefore, have always been a subject of deepest interest both to the popular and the scientific mind—an interest intensified by the splendors of mountain scenery and the perils of mountain exploration. The study of mountains is therefore coeval with the study of geology. As early as the beginning of the present century Constant Prevost observed that most characteristic structure of mountains—viz, their folded strata—and inferred their formation by lateral pressure. All subsequent writers have assumed lateral pressure as somehow concerned in the formation of mountains. But that the whole height of mountains is due wholly to this cause was not generally admitted or even imagined until recently. It was universally supposed that mountains were lifted by volcanic forces from beneath, that the lifted strata broke along the top of the arch, and melted matter was forced through between the parted strata, pushing them back and folding them on each side. And hence the typical form of mountain ranges is that of a granite axis along the crest and folded strata on each flank. But attention has lately been drawn to the fact that some mountains, as, for example, the Appalachian, the Uintah, etc., consist of folded strata alone, without any granite axis. In such ranges it is plain that the whole height is due not to any force acting from below, but to a lateral pressure crushing and folding the strata, and a corresponding thickening and bulging of the same along the line of crushing. Then the idea was applied to all mountain ranges. So soon as the prodigious amount of erosion suffered by mountains, greater often than all that is left of them, was fully appreciated, it became evident that the granite axis so characteristic of mountains was not necessarily pushed up from beneath and protruded through the parted strata, but was in many cases only a submountain core of igneous matter slowly cooled into granite and exposed by subsequent erosion greatest along the crest.

Next, attention was drawn to the enormous thickness of the strata involved in the folded structure of mountains. From this it became evident that the places of mountains before they were formed were marginal sea bottoms off the coasts of continents, and receiving the whole washings of the continents. Thus the steps of the process of mountain formation were (1) accumulation of sediments on offshore sea bottoms until by pari passu subsidence an enormous thickness was attained. This is the preparation. (2) A yielding along these lines to the increasing lateral pressure with folding and bulging of the strata along the line of yielding, until the mountain emerges above the ocean and is added to the land as a coast range. This is mountain birth. (3) As soon as it appears above the water it is attacked by erosive agents. At first the rising by continuance of the crushing and bulging is in excess of the erosion, and the mountain grows. This is mountain youth. (4) Then supply and waste balance one another, and we have mountain maturity. (5) Then the erosive waste exceeds the growth by upbulging, and mountain decay begins. (6) Finally, the erosive forces triumph and the mountain is clean swept away, leaving only the complexly folded rocks of enormous thickness to mark the place of a former mountain. This is mountain death. Such, briefly, is the life history of a mountain range.

In all this we have said nothing about causes. In this connection there are two points of especial importance: (1) Why does the yielding to lateral pressure take place along lines of thick sediments? (2) What is the cause of the lateral pressure?

1. *Cause of yielding to lateral pressure along lines of thick sediments.*—The earth was once very hot. It is still very hot within, and still very slowly cooling. If sediments accumulate upon a sea bottom the interior heat will tend to rise so as to keep at the same distance from the surface. If the sediments are very thick, say 5 to 10 miles, their lower parts will be invaded by a temperature of not less than 500° to 1,000° F. This temperature, in the presence of water (the included water of the sediments), would be sufficient to produce softening or even fusion of the sediments and of the sea floor on which they rest. This would establish a line of weakness, and therefore a line of yielding, crushing, folding, bulging, and thus a mountain range. In the first formation of a range, therefore, there would necessarily be a submountain mass of fused or semifused matter which by the lateral crushing might be squeezed into cracks or fissures, forming dikes. But in any case the submountain mass would cool into a granite core which by erosion may be exposed along the crest. The explanation seems to be satisfactory.

2. *Cause of lateral pressure.*—No question in geology has been more discussed than this, and yet none is more difficult and the solution of which is more uncertain. But the most obvious and as yet the most probable view is that it is the result of the secular contraction of the earth which has gone on throughout the whole history, and is still going on.

It is admitted by all that in an earth cooling from primal incandescence there must come a time when the surface, having become substantially cool and receiving heat also from the sun, would no longer cool or contract, but the interior, being still incandescently hot, would continue to cool and contract. The interior, therefore, cooling and contracting faster than the exterior crust, the latter following down the ever-shrinking nucleus, would be thrust upon itself by a lateral or tangential pressure which would be simply irresistible. If the earth crust were a hundred times more rigid than it is, it still must yield to the enormous pressure. It does yield along its weakest lines with crushing, folding, bulging, and the formation of mountain ranges.

This is the barest outline of the so-called "contractional theory of mountain formation." Very many objections have been brought against it, some of them answerable and completely answered, but the complete answer to others must be left to the next century. Perhaps the greatest objection of all is the apparent insufficiency of the cause to produce the enormous amount of folding found not only in existing mountains but in the folded structure of rocks where mountains no longer exist. But it will be observed that I have thus far spoken only of contraction by loss of heat. Now, not only has this cause been greatly underestimated by objectors, but, as shown by Davison and especially by Van Hise, there are many other and even greater causes of contraction. It would be out of place to follow the discussion here. The subject is very complex, and not yet completely settled.

We have given the barest outline of the history of mountain ranges and of the theory of their formation as worked out in the last third of the present century, and, I might add, chiefly by American geologists. So true is this that by some it has been called the "American theory."

Oscillatory movements of the earth's crust over wide areas.—We have already spoken of these as modifying the effect of the ocean-basin-making movements, and therefore now touch them very lightly. These differ from the movements producing oceanic basins on the one hand and mountain ranges on the other by the fact that they are not continuously progressive in one direction, but oscillatory—now up, now down, in the same place. Again, they do not involve contraction of the whole earth, but probably are always more or less local and compensatory—i. e., rising in one place is compensated by down sinking in some other place. Nevertheless, they often affect very wide areas—sometimes, indeed, of more than continental extent—as, for example, in the crust movements of the Quaternary period or ice age.

These are by far the most frequent and most conspicuous of all crust movements—not only now, but also in all geological times. If ocean-basin-forming movements are the underlying cause and condition of the evolution of the earth, these wide oscillations, by increasing and decreasing the size and height of continents and changing greatly their contours, have determined all the details of the drama enacted on the surface, and were the determining cause of the varying rates and directions of the evolution of the organic kingdom. These were the cause of the unconformities and the corresponding apparent wholesale changes in species so common in the rocky strata, and which gave rise to the doctrine of catastrophism of the early geologists. These also have so greatly modified the contours of the continents and their size by temporary increase or decrease that they have obscured the general law of the steady development of these, and therefore their substantial permanency.

Although the most important of all crust movements in determining the whole history of the earth, and especially of the organic kingdom, we shall dwell no further on them, because no progress has yet been made in their explanation. This, too, must be left to the workers of the twentieth century.

The principle of isostasy.—The principle of static equilibrium as applied to earth forms was first brought forward (as so many other valuable suggestions and anticipations in many departments of science) by the wonderfully fertile mind of Sir John Herschel, and used by him in the explanation of the sinking of river deltas under the increasing weight of accumulating sediments.[1] It was afterwards applied to continental masses by Archbishop Pratt[2] and by the royal astronomer, Professor Airy.[3] But for its wide application as a principle in geology, its clear definition, and its embodiment in an appropriate name we are indebted to Major Dutton, United States Army.[4]

The principle may be briefly stated as follows: A globe so large as the earth, under the influence of its own gravity, must behave like a very stiffly viscous body—that is, the general form of the earth and its greatest inequalities must be in substantial static equilibrium. For example, the general form of the earth is oblate spheroid, because that is the only form of equilibrium of a rotating body. Rotation determines a distribution of gravity with latitude which brings about this form. With any other form the earth would be in a state of strain to which it must slowly yield and finally relieve itself by becoming oblate. If the rotation stopped, the earth would accommodate itself to the new distribution of gravity and become spherical.

The same is true of the large inequalities of surface. Oceanic basins and continental arches must be in static equilibrium or they could not sustain themselves. In order to be in equilibrium the suboceanic material must be as much more dense than the continental and subcontinental material as the ocean bottoms are lower than the continental surfaces. Such static equilibrium, by difference of density, is completely explained by the mode of formation of oceanic basins already given.

So also plateaus and great mountain ranges are at least partly sustained by gravitative equilibrium, but partly also by earth rigidity. It is only the smaller inequalities, such as ridges, peaks, valleys, etc., that are sustained by earth rigidity alone.

These conclusions are not reached by physical reasonings alone, but are also confirmed by experimental investigations. For example, a plumb line on the plains of India is deflected indeed toward the Himalayas, as it ought to be, but much less than it would be if the mountain and submountain mass were not less dense and the suboceanic material more dense than the average.[5] Again, gravitative determinations by pendulum oscillations, undertaken by the United States along a line from the Atlantic shore to Salt Lake City, show that the largest inequalities, such as the Appalachian bulge, the Mississippi basin hollow, and the Rocky Mountain bulge, are in gravitative equilibrium—i. e., the mountain and submountain material is as much

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[1] Philosophical Magazine, Vol. II, p. 212, 1837; Quarterly Journal of Geological Society, Vol. II, p. 548, 1837.

[2] Philosophical Magazine, Vol. IX, p. 231, and Vol. X, p. 240, 1855.

[3] Philosophical Transactions, 1855, p. 101.

[4] Philosophical Society of Washington, 1892.

[5] Pratt, Philosophical Magazine, Vol. IX, p. 231, 1855; Vol. X, p. 340, 1855; Vol. XVI, p. 401, 1858.

lighter as the mountain region is higher than the Mississippi basin region.

Now, so sensitive is the earth to changes of gravity that, given time enough, it responds to increase or decrease of pressure over large areas by corresponding subsidence or elevation. Hence, all places where great accumulations of sediment are going on are sinking under the increased weight, and, contrarily, all places where excessive erosion is going on, as, for example, on high plateaus and great mountain ranges, are rising by relief of pressure.

This principle of isostasy is undoubtedly a valuable one, which must be borne in mind in all our reasonings on crust movements, although its importance has been exaggerated by some enthusiastic supporters. Its greatest importance is not as a cause initiating crust movements or determining the features of the earth, but rather as conditioning and modifying the results produced by other causes. The idea belongs wholly to the latter half of the present century. Commencing about 1840, it has grown in clearness and importance to the present time.

THE AGE OF THE EARTH.

Until almost the beginning of the present century the general belief in all Christian countries was that not only the earth and man, but the whole cosmos, began to exist about six thousand to seven thousand years ago; furthermore, that all was made at once without natural process, and have remained substantially unchanged ever since. This is the old doctrine of the supernatural origin and substantial permanency of the earth and its features. Among intelligent and especially scientific men this doctrine, even in the eighteenth century, began to be questioned, although not publicly; for in 1751 Buffon was compelled by the Sorbonne to retract certain views concerning the age of the earth, published in his Natural History in 1749.[1] Remnants of the old belief lingered even into the early part of the present century, and may even yet be found hiding away in some of the remote corners of civilized countries. But with the birth of geology, and especially through the work of Hutton in Scotland, Cuvier in France, and William Smith in England, the much greater—the inconceivably great—antiquity of the earth and the origin of its present forms, by gradual changes which are still going on, was generally acknowledged. Indeed, as already said, this is the fundamental idea of geology, without which it could not exist as a science.

Geology has its own measures of time—in eras, periods, epochs, ages, etc.—but it is natural and right that we should desire more accurate estimates by familiar standards. How old, then, is the earth, especially the inhabited earth, in years? Geologists have attempted

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[1] Lyell's Principles of Geology, eighth edition, p. 41.

to answer this question by estimates based on the rates of sedimentation and erosion, or else on the rate of changes of organic forms by struggle for life and survival of the fittest. Physicists have attempted to answer the same question by calculations based on known laws of dissipation of energy in a cooling body, such as the sun or the earth. The results of the two methods differ widely. The estimates of the geologists are enormous, and growing ever greater as the conditions of the problem are better understood. Nothing less than several hundred million years will serve their purpose. The estimates of the physicists are much more moderate, and apparently growing less with each revision. The latest results of King and Kelvin give only twenty to thirty millions.[1] This the geologist declares is absurdly inadequate. He can not work freely in so narrow a space—he has not elbow room.

The subject is still discussed very earnestly, but with little hope of definite conclusion. One thing, however, must be remarked. Both parties assume—the geologist tacitly, the physicist avowedly—the nebular hypothesis of the origin of the solar system, and therefore the early incandescent fluid condition of the earth as the basis of all his reasonings. Now, while this is probably the most reasonable view, it is not so certain that it can be made the basis of complex mathematical calculation. There is a possible alternative theory, viz, the meteoric theory, which is coming more and more into favor. According to this view the planets may have been formed by aggregation of meteoric swarms and the heat of the earth produced by the collision of the meteors in the act of aggregation. According to the one view (the nebular) the heat is all primal, and the earth has been only losing heat all the time. According to the other, the aggregation and the heating are both gradual, and may have continued even since the earth was inhabited. According to the one, the spendthrift earth wasted nearly all its energy before it became habitable or even a crust was formed, and therefore the habitable period must be comparatively short. According to the other, the cooling and the heating, the expenditure and the income, were going on at the same time, and therefore the process may have lasted much longer.

The subject is much too complex to be discussed here. Suffice it to say that on this latter view not only the age of the earth, but many other fundamental problems of dynamical geology, would have to be recalculated. The solution of these great questions must also be left to the next century. In the meantime we simply draw attention to two very recent papers on the subject, viz, that of Lord Kelvin,[2] and criticism of the same by Chamberlin.[3]

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[1] Clarence King, American Journal of Science, pp. 45–51, 1893; Kelvin, Science, Vol. IX, p. 665, 1899. [Smithsonian Report, 1898.]

[2] Science, Vol. IX, p. 665, 1899. [Smithsonian Report, 1898.]

[3] Ibid., p. 889, and Vols. X and XI, 1899. [Smithsonian Report, 1899.]

ANTIQUITY AND ORIGIN OF MAN.

Even after the great antiquity of the earth and its origin and development by a natural process were generally accepted, still man was believed, even by the most competent geologists, to have appeared only a few thousand years ago. The change from this old view took place in the last half of the present century, viz, about 1859, and, coming almost simultaneously with the publication of Darwin's Origin of Species, prepared the scientific mind for entertaining, at least, the idea of man's origin by a natural process of evolution.

Evidences of the work of man—flint implements, associated with the bones of extinct animals and therefore showing much greater age than usually accepted—had been reported from time to time, notably those found in the river Somme by Boucher de Perthes. But the prejudice against such antiquity was so strong that geologists with one accord, and without examination, pooh-poohed all such evidence as incredible. It was Sir Joseph Prestwich who, in 1859, first examined them carefully, and published the proofs that convinced the geological world that early man was indeed contemporaneous with the extinct animals of the Quaternary period, and that the time must have been many times greater than usually allowed.[1]

Since that time confirmatory evidence has accumulated, and the earliest appearance of man has been pushed back first to the late Glacial, then to the Middle Glacial, and finally, in Mr. Prestwich's Plateau Gravels, to the early Glacial or possibly preglacial times.

Still, however, in every case earliest man was unmistakably man. No links connecting him with other anthropoids had been found. Very recently, however, have been found, by Du Bois, in Java, the skull, teeth, and thigh bone of what seems to be a veritable missing link, named by the discoverer Pithecanthropus erectus. The only question that seems to remain is whether it should be regarded as an ape more manlike than any known ape, or a man more apelike than any yet discovered. The age of this creature was either latest Pliocene or earliest Quaternary.

BREAKS IN THE GEOLOGICAL RECORD AND THEIR SIGNIFICANCE.

From the earliest times of geologic study there have been observed unconformities of the strata and corresponding changes in the fossil contents. Some of these unconformities are local and the changes of organic forms inconsiderable, but sometimes they are of wider extent and the changes of life system greater. In some cases the unconformity is universal or nearly so, and in such cases we find a complete and apparently sudden change in the fossil contents. It was these universal

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[1] Life and Letters of Sir Joseph Prestwich, pp. 124 et seq.

breaks that gave rise to the belief in the occurrence of violent catastrophes and corresponding wholesale exterminations and re-creations of faunas and floras.

It is evident, however, on a little reflection, that every such unconformity indicates a land period at the place observed, and therefore a time unrecorded in strata and fossils at that place—i. e., a lost interval—certain leaves missing from the book of time. And if the unconformity be widespread, the lost interval is correspondingly great. It is therefore probable that change of species went on slowly and uniformly all the time, although not recorded at that place. Intermediate strata may be and often are found elsewhere, and the supposed lost interval filled. The record was continuous and the changes uniform, but the record is not all found in one place. The leaves of the book of time are scattered here and there, and it is the duty of the geologist to gather and arrange them in proper order, so that the record may read continuously.

This is the uniformitarian view, and is undoubtedly far truer than the catastrophic. But the objection to it is that in the case of very widespread unconformities, such as occurred several times in the history of the earth, the changes of organisms are so great that if the rate of change was uniform the lost interval must have been equal to all the rest of the history put together. Therefore we are compelled to admit that in the history of the earth there have been periods of comparative quiet (not fixedness) during which evolutionary changes were slow and regular, and periods of revolution during which the changes were much more rapid, but not catastrophic. This is exactly what we ought to expect on the idea of gradual evolution of earth forms by secular cooling, for in the gradual contraction of the earth there must come times of general readjustment of the crust to the shrinking nucleus. These readjustments would cause great changes in physical geography and climate, and corresponding rapid changes in organic forms. In addition to this, the changes in physical geography and climate would cause extensive migrations of species, and therefore minglings of faunas and floras, severer struggles of competing forms, and more rapid advance in the steps of evolution. Among these changes of organic forms there would arise and have arisen new dominant types, and these, in their turn, would compel new adjustment of relations and still further hasten the steps of evolution. Such changes, whether geographic, or climatic, or organic, would not be simultaneous all over the earth, but propagated from place to place, until quiet was reestablished and a new period of comparative stability and prosperity commenced.

This view is a complete reconciliation of catastrophism and uniformitarianism, and is far more rational than either extreme.

Critical periods in the history of the earth.—Such periods of rapid change may well be called critical periods or revolutions. They are marked by several characteristics: (1) By widespread oscillations of the earth's crust, and therefore by almost universal unconformities. (2) By widespread changes of physical geography, and therefore by great changes in climate. (3) By great and widespread changes in organic forms, produced partly by the physical changes and partly by the extensive migrations. (4) By the evolution of new dominant types, which are also the cause of extensive changes in species. (5) Among the physical changes occurring at these times is the formation of great mountain ranges. The names of these critical periods or revolutions are often taken from the mountain range which form their most conspicuous features.

There have been at least four of these critical periods, or periods of greatest change: (1) The pre-Cambrian or Laurentian revolution; (2) the post-Paleozoic or Appalachian; (3) the post-Cretaceous or Rocky Mountain; (4) the post-Tertiary or Glacial revolution.

Now, as these critical periods separate the primary divisions of time—the eras—it follows that the present—the Age of Man—is an era. It may be called the Psychozoic Era. These views have been mainly advocated by the writer of this sketch, but I believe that, with perhaps some modification in statement, they would be accepted by most geologists as a permanent acquisition of science. [1]

GEOLOGICAL CLIMATES.

Attention was first drawn to this subject by the apparently unique phenomena of the Glacial epoch.

For nearly a century past Alpine glaciers, their structure, their mysterious motion, and their characteristic erosive effects, have excited the keenest interest of scientific men. But until about 1840 the interest was purely physical. It was Louis Agassiz who first recognized ice as a great geological agent. He had long been familiar with the characteristic marks of glacial action, and with the fact that Alpine glaciers were far more extensive formerly than now, and had, moreover, conceived the idea of a Glacial epoch—an ice age in the history of the earth. With this idea in his mind, in 1840 he visited England, and found the marks of glaciers all over the higher regions of England and Scotland. He boldly announced that the whole of northern Europe was once covered with a universal ice sheet. A few years later he came to the United States, and found the tracks of glaciers everywhere, and again astonished the world by asserting that the whole northern part of the North American continent was modeled by a moving ice

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[1] Critical Periods, etc., American Journal of Science, Vol. XIV, p. 99, 1877; Bulletin of the Geological Department of the University of California, Vol. I, No. 11, 1895.

sheet. This idea has been confirmed by all subsequent investigation, especially here in America.

But it would be strange, indeed, if the cold of the Glacial epoch should be absolutely unique. Attention was soon called to similar marks in rocks of other geological periods, especially in the Permian of the Southern Hemisphere. This opened up the general question of geological climates and their causes.

Perhaps no subject connected with the physics of the earth is more obscure and difficult than this. The facts, as far as we know them, are briefly as follows: (1) All the evidence we have point to a high, even an ultra-tropical, climate in early geological times; (2) all the evidence points to a uniform distribution of this early high temperature, so that the zonal arrangement of temperatures, such as characterizes present climates, did not then exist; (3) temperature zones were apparently first introduced in the late Mesozoic (Cretaceous) or early Tertiary times, and during the Tertiary the colder zones were successively added, until at the end there was formed a polar ice-cap as now.

Thus far all might be explained by progressive cooling of the earth and progressive clearing of the atmosphere of its excess CO_2 and aqueous vapor. But (4) from time to time (i. e., at critical periods) there occurred great oscillations of temperature, the last and probably the greatest of these being the Glacial period. The cause of these great oscillations of temperature, and especially the cause of the glacial climate, is one of the most interesting and yet one of the obscurest, and therefore one of most hotly disputed, points in geology. Indeed, the subject has entered into the region of almost profitless discussion. We must wait for further light and for another century. Only one remark seems called for here. It is in accordance with a true scientific method that we should exhaust terrestrial causes before we resort to cosmical. The most usual terrestrial cause invoked is the oscillation of the earth's crust. But recently Chamberlin, in a most suggestive paper,[1] has invoked oscillations in the composition of the atmosphere, especially in its proportion of CO_2, as the immediate cause, although this in turn is due to oscillations of the earth's crust.

THE NEW GEOLOGY.

Heretofore the geological history of the earth has been studied only in the record of stratified rocks and their contained fossils. But in every place there have been land periods in which, of course, erosion took the place of sedimentation. This kind of record is very imperfect, because there are no fossils. Until recently no account was taken of these erosion periods except as breaks of indefinite length in the record—as lost intervals. But now, and mainly through the work

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[1] Journal of Geology, Vol. VI, p. 597, 1898, and Vol. VII, p. 545, 1899.

of American geologists, interpretation of these erosion periods has fairly commenced, and so important has this new departure in the study of geology seemed to some that it has been hailed as a new era in geology, connecting it more closely with geography. Heretofore former land periods were recognized by unconformities, and the amount of time by the degree of change in the fossils, but now the amount of time is estimated in existing land surfaces by topographic forms alone. This idea was introduced into geology by Maj. J. W. Powell, and has been applied with success by William Morris Davis, W J McGee, and others.

The principle is this: Land surface subject to erosion and standing still is finally cut down to gently sweeping curves, with low, rounded divides and broad, shallow troughs. Such a surface is called by Davis a "peneplain." Such a peneplain is characteristic of old topography. If such a surface be again lifted to higher level, the rivers again dissect it by ravines, which are deep and narrow in proportion to the amount and rate of the uplift. If the land again remains steady, the sharply dissected surface is again slowly smoothed out to the gentle curves of a peneplain. If, on the contrary, the surface be depressed, the rivers fill up the channels with sediment, which, on reelevation, is again dissected. Thus the whole ontogeny of land surfaces have been studied out, so that their age may be recognized at sight.

Thus, while heretofore the more recent movements of the crust were supposed to be readable only on coast lines and by means of the old sea strands, now we read with equal ease the movements of the interior by means of the physiognomy of the topography, and especially the structure of the river channels. Moreover, while heretofore the history of the earth was supposed to be recorded only in stratified rock and their contained fossils, now we find that recent history is recorded and may be read also in the general topography of the land surfaces. Geography is studied no longer as mere description of earth forms, but also as to the causes of these forms; no longer as to present forms, but also as to the history of their becoming. Thus geography, by its alliance with geology, has become a truly scientific study, and as such is now introduced into the colleges and universities. It is this alliance with geology which has caused the dry bones of geographic facts to live. It is this which has created a soul under the dry "ribs of this death." This mode of study of the history of the earth has just commenced. How much will come of it is yet to be shown in the next century.

In this connection it is interesting to trace the effect of environment on geological reasonings in different countries. Heretofore, especially in England, what we have called peneplains were usually attributed to marine denudation—i. e., to cutting back of a coast line by constant action of the waves, leaving behind a level submarine plateau, which is afterwards raised above sea level and dissected by rivers. American geologists, on the contrary, are apt to regard such level surfaces as the final result of aerial degradation or a base level of rain and river erosion. The same difference is seen in the interpretation of glacial phenomena. Until recently English geologists were inclined to attribute more to iceberg; Americans more to land ice. Again, in England coast scenery is apt to be attributed mainly to the ravages of the sea, while in America we attribute more to land erosion combined with subsidence of the coast line. In a word, in the tight little sea-girt island of Great Britain, where the ravages of the sea are yearly making such serious inroads upon the area of the land, it is natural that the power of the sea should strongly affect the imagination and impress itself on geological theories, and tend, perhaps, to exaggeration of sea agencies, while the broad features of the American continent and the evidences of prodigious erosion in comparatively recent geological time tend to the exaggeration of erosive agency of rain and rivers. These two must be duly weighed and each given its right proportion in the work of earth sculpture.

PALEONTOLOGY.

Paleontology at first attracted attention mainly by the new and strange life forms which it revealed. It is the interest of a zoological garden. This interest is of course perennial, but can hardly be called scientific. Geology at first was a kind of wonder book.

Next fossils, especially marine shells, were studied as characteristic forms denoting strata of a particular age. They were coins by which we identify certain periods of history. They were "medals of creation." It was in this way chiefly that William Smith, the founder of English stratigraphic geology, used them. It was in this way that Lyell and all the older geologists, until the advent of evolution, were chiefly interested in them.

It was Cuvier, the great zoologist and comparative anatomist, who, in the beginning of the present century, first studied fossils, especially mammalian fossils, from the zoological point of view, i. e., as to their affinities with existing animals. Cuvier's studies of the vertebrates of the Paris basin may be said to have laid the foundation of scientific paleontology from this point of view.

Thenceforward two views of paleontology and two modes of study gradually differentiated from one another—the one zoological, the other geological. In the one case we study fossils in taxonomic groups—i. e., as species, genera, families, orders, etc.—and trace the gradual evolution of each of these from generalized forms to their specialized outcomes, completing, as far as possible, the genetic chain through all time; in the other, we study fossils in faunal groups, as successive geological faunas, and the geographic diversity in each geological period, i. e., the evolution of geologic faunas and the causes of geographic diversity in each. In a word, we study the laws of distribution of faunas in time geologically and in space geographically, and the causes of these laws in each case. The first is strictly a branch of zoology and botany, and we leave it to these specialists. The second alone belongs properly to geology. In this purely geologic paleontology, as seen from its scope given above, there are many questions of widest philosophical interest which are only now attracting the attention they deserve. I only touch lightly two which have been brought forward in these very last years of the century.

I. *General laws of faunal evolution.*—The evolution of the organic kingdom from this strictly geological point of view may be briefly formulated as follows:

1. Throughout all geological time there has been a general movement upward and onward, as it were abreast, everywhere. If this were all, there would be only geological progress, but no geographical diversity. Geological history would be the same everywhere. A time horizon would be easily determined by identity of fossil species. This we know is not true. Therefore there are other elements besides this.

2. In different countries, isolated from one another and under different conditions, evolution takes different directions and different rates, producing geographical diversity in each geological period. This diversity increases with time as long as the isolation continues. If this were all, the geographical diversity by continued divergence would have become so great that it would be impossible even approximately to determine any geological horizon. The history of each country must be studied for itself. A general history of the earth would be impossible. But this also is not true. There is, therefore, still another element.

3. From time to time, at long intervals, i. e., critical periods, there are widespread readjustments of the crust to internal strain, determining changes of physical geography and of climate, and therefore wide migrations of species, with mingling and conflict of faunas. This would produce more rapid movement of evolution, but at the same time more or less complete obliteration of geographical diversity.

4. After these periods of migrations and minglings there would be reisolations in new localities, and the process of diversification would recommence and increase as long as the isolation continues.

The last of these critical periods of migrations and minglings and struggles for life among competing species was the Glacial epoch, or ice age. Therefore the present geographical distribution of species was largely determined by the extensive migrations of that time.

II. *Cosmopolitan and provincial faunas.*—There are apparently in the history of the earth periods of widespread or cosmopolitan faunas, alternating with localized or provincial faunas. The cosmopolitan periods are usually times of prevalence of limestones or organic sediments, and the fossils are very abundant. The provincial periods are usually characterized by sandstones and shales or mechanical sediments, and are comparatively poor in fossils. Moreover, it is believed that the cosmopolitan limestone periods are oceanic periods—i. e., periods of wide oceans and lower and smaller continents and little erosive activity, while the sandstone periods, characterized by provincial faunas, are periods of higher and larger continents, and therefore of great erosion and abundant mechanical sedimentation.

Now, according to Chamberlin, these remarkable alternations are due to oscillations of the crust, in which the continents are alternately lifted and depressed. It must be remembered that abyssal faunas are almost unknown among fossils. This is the necessary result of substantial permanency of oceanic basins. The whole geological record is in shallow-water faunas. These shallow waters are along continental shore lines and in interior continental seas. According to Chamberlin again, during a period of continental depression all the flat continental margins are submerged, forming broad submarine platforms, and the lower interior portions of the continents are also submerged, forming wide and shallow interior seas. Under these conditions continental waste, and therefore sand and clay sediments, are reduced to a minimum. Life, animal and vegetal, abounds, and therefore much limestone is formed. The oceans are widely connected with one another, and therefore the faunas are widespread or cosmopolitan. During the period of elevation, on the contrary, the continents are extended to the margin of the deep oceanic basins, the broad, shallow, submarine platforms are abolished, the interior seas are also abolished, the shallow-water areas are reduced to isolated bays, and their faunas are peculiar or provincial. Also, elevated and enlarged continents give rise to maximum erosion, and therefore abundant sediments of sandstone and clay, and comparative poverty of life and therefore of limestone. Chamberlin also gives reasons why the oceanic periods should be warm, humid, equable in temperature, and the atmosphere highly charged with CO_2, and therefore highly favorable to abundant life, both vegetal and animal, while land periods would be drier and cooler, the atmosphere deficient in CO_2, and therefore cold from that cause and in many ways unfavorable to abundant life.

These extremely interesting views, however, must be regarded as still on trial, as a provisional hypothesis to be sifted, confirmed, or rejected, or in any case modified, in the next century.

Lastly, it is interesting to note the ever-increasing part taken by American geologists in the advance of this science. There has been through the century a gradual movement of what might be called the center of gravity of geological research westward, until now, at its end, the most productive activity is here in America. This is not due to any superiority of American geologists, but to the superiority of their opportunities. Dana has well said that America is the type continent of the world. All geological problems are expressed here with a clearness and a simplicity not found elsewhere. We must add to this the comparative recency of geological study in this rich field. In Europe the simpler and broader problems are already worked out, and all that remain are difficult problems requiring much time. In America, on the contrary, not only are all problems expressed in simpler terms, but many great and broad problems are still awaiting solution. For these reasons the greatest activity in research, and the most rapid advance during the next century, will probably be here in America.

EVOLUTIONAL GEOLOGY.[1]

By Prof. W. J. Sollas, F. R. S.

EVOLUTIONAL GEOLOGY.

The close of one century, the dawn of another, may naturally suggest some brief retrospective glance over the path along which our science has advanced, and some general survey of its present position from which we may gather hope of its future progress; but other connection with geology the beginnings and endings of centuries have none. The great periods of movement have hitherto begun, as it were, in the early twilight hours, long before the dawn. Thus the first step forward, since which there has been no retreat, was taken by Steno in the year 1669; more than a century elapsed before James Hutton (1785) gave fresh energy and better direction to the faltering steps of the young science; while it was less than a century later (1863) when Lord Kelvin brought to its aid the powers of the higher mathematics and instructed it in the teachings of modern physics. From Steno onward the spirit of geology was catastrophic; from Hutton onward it grew increasingly uniformitarian; from the time of Darwin and Kelvin it has become evolutional. The ambiguity of the word "uniformitarian" has led to a good deal of fruitless logomachy, against which it may be as well at once to guard by indicating the sense in which it is used here. In one way we are all uniformitarians, i. e., we accept the doctrine of the "uniform action of natural causes," but, as applied to geology, uniformity means more than this. Defined in the briefest fashion it is the geology of Lyell. Hutton had given us a "Theory of the Earth," in its main outlines still faithful and true, and this Lyell spent his life in illustrating and advocating, but as so commonly happens the zeal of the disciple outran the wisdom of the master, and mere opinions were insisted on as necessary dogma. What did it matter if Hutton, as a result of his inquiries into terrestrial history, had

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[1] Opening address by Prof. W. J. Sollas, D. Sc., LL. D., F. R. S., president of the Section of Geology of the British Association for the Advancement of Science, 1900. Reprinted from Nature No. 1611, vol. 62, September 13, 1900.

declared that he found no vestige of a beginning, no prospect of an end? It would have been marvelous if he had! Consider that when Hutton's "Theory" was published William Smith's famous discovery had not been made, and that nothing was then known of the orderly succession of forms of life, which it is one of the triumphs of geology to have revealed; consider, too, the existing state of physics at the time, and that the modern theories of energy had still to be formulated; consider also that spectroscopy had not yet lent its aid to astronomy and the consequent ignorance of the nature of nebulæ; and then, if you will, cast a stone at Hutton. With Lyell, however, the case was different; in pressing his uniformitarian creed upon geology he omitted to take into account the great advances made by its sister sciences, although he had knowledge of them, and thus sinned against the light. In the last edition of the famous "Principles" we read: "It is a favorite dogma of some physicists that not only the earth, but the sun itself, is continually losing a portion of its heat, and that as there is no known source by which it can be restored we can foresee the time when all life will cease to exist on this planet, and on the other hand we can look back to a period when the heat was so intense as to be incompatible with the existence of any organic beings such as are known to us in the living or fossil world. * * * A geologist in search of some renovating power by which the amount of heat may be made to continue unimpaired for millions of years, past and future, in the solid parts of the earth * * * has been compared by an eminent physicist to one who dreams he can discover a source of perpetual motion and invent a clock with a self-winding apparatus. But why should we despair of detecting proofs of such regenerating and self-sustaining power in the works of a Divine Artificer?" Here we catch the true spirit of uniformity; it admittedly regards the universe as a self-winding clock, and barely conceals a conviction that the clock was warranted to keep true Greenwich time. The law of the dissipation of energy is not a dogma, but a doctrine drawn from observation, while the uniformity of Lyell is in no sense an induction; it is a dogma in the narrowest sense of the word, unproved, incapable of proof; hence perhaps its power upon the human mind; hence also the transitoriness of that power. Again, it is only by restricting its inquiries to the stratified rocks of our planet that the dogma of uniformity can be maintained with any pretense of argument. Directly we begin to search the heavens the possibility, nay even the likelihood, of the nebular origin of our system, with all that it involves, is borne in upon us. Lyell therefore consistently refused to extend his gaze beyond the rocks beneath his feet, and was thus led to do a serious injury to our science; he severed it from cosmogony, for which he entertained and expressed the most profound contempt, and from the mutilation thus inflicted geology is only at length making a slow and painful recovery. Why do I dwell on these facts? To depreciate Lyell? By no means. No one is more conscious than I of the noble service which Lyell rendered to our cause; his reputation is of too robust a kind to suffer from my unskillful handling, and the fame of his solid contributions to science will endure long after these controversies are forgotten. The echoes of the combat are already dying away, and uniformitarians, in the sense already defined, are now no more; indeed, were I to attempt to exhibit any distinguished living geologist as a still surviving supporter of the narrow Lyellian creed, he would probably feel, if such a one there be, that I was unfairly singling him out for unmerited obloquy.

Our science has become evolutional, and in the transformation has grown more comprehensive; her petty parochial days are done, she is drawing her provinces closer around her, and is fusing them together into a united and single commonwealth—the science of the earth.

Not merely the earth's crust, but the whole of earth-knowledge is the subject of our research. To know all that can be known about our planet, this, and nothing less than this, is its aim and scope. From the morphological side geology inquires, not only into the existing form and structure of the earth, but also into the series of successive morphological states through which it has passed in a long and changeful development. Our science inquires also into the distribution of the earth in time and space; on the physiological side it studies the movements and activities of our planet; and not content with all this it extends its researches into ætiology and endeavors to arrive at a science of causation. In these pursuits geology calls all the other sciences to her aid. In our commonwealth there are no outlanders; if an eminent physicist enter our territory we do not begin at once to prepare for war, because the very fact of his undertaking a geological inquiry of itself confers upon him all the duties and privileges of citizenship. A physicist studying geology is by definition a geologist. Our only regret is, not that physicists occasionally invade our borders, but that they do not visit us oftener and make closer acquaintance with us.

EARLY HISTORY OF THE EARTH—FIRST CRITICAL PERIOD.

If I am bold enough to assert that cosmogony is no longer alien to geology, I may proceed further and, taking advantage of my temerity, pass on to speak of things once not permitted to us. I propose, therefore, to offer some short account of the early stages in the history of the earth. Into its nebular origin we need not inquire; that is a subject for astronomers. We are content to accept the infant earth from their hands as a molten globe ready made, its birth from a gaseous nebula duly certified. If we ask, as a matter of curiosity, what was the origin of the nebula, I fear even astronomers can not tell us.

There is an hypothesis which refers it to the clashing of meteorites, but in the form in which this is usually presented it does not help us much. Such meteorites as have been observed to penetrate our atmosphere and to fall onto the surface of the earth prove on examination to have had an eventful history of their own, of which not the least important chapter was a passage through a molten state; they would thus appear to be the products rather than the progenitors of a nebula.

We commence our history, then, with a rapidly rotating molten planet, not impossibly already solidified about the center and surrounded by an atmosphere of great depth, the larger part of which was contributed by the water of our present oceans, then existing in a state of gas. This atmosphere, which exerted a pressure of something like 5,000 pounds to the square inch, must have played a very important part in the evolution of our planet. The molten exterior absorbed it to an extent which depended on the pressure, and which may some day be learned from experiment. Under the influence of the rapid rotation of the earth the atmosphere would be much deeper in equatorial than polar regions, so that in the latter the loss of heat by radiation would be in excess. This might of itself lead to convectional currents in the molten ocean. The effect on the atmosphere is very difficult to trace, but it is obvious that if a high-pressure area originated over some cooler region of the ocean the winds blowing out of it would drive before them the cooler superficial layers of molten material, and as these were replaced by hotter lava streaming from below the tendency would be to convert the high into a low pressure area and to reverse the direction of the winds. Conversely under a low-pressure area the inblowing winds would drive in the cooler superficial layers of molten matter that had been swept away from the anticyclones. If the difference in pressure under the cyclonic and anticyclonic areas were considerable, some of the gas absorbed under the anticyclones might escape beneath the cyclones, and in a later stage of cooling might give rise to vast floating islands of scoria. Such islands might be the first foreshadowings of the future continents. Whatever the ultimate effect of the reaction of the winds on the currents of the molten ocean, it is probable that some kind of circulation was set up in the latter. The universal molten ocean was by no means homogeneous. It was constantly undergoing changes in composition as it reacted chemically with the internal metallic nucleus; its currents would streak the different portions out in directions which in the northern hemisphere would run from northeast to southwest, and thus the differences which distinguish particular petrological regions of our planet may have commenced their existence at a very early stage. Is it possible that as our knowledge extends we shall be able by a study of the distribution of igneous rocks and minerals to draw some conclusions as to the direction of these hypothetical lava currents? Our planet was profoundly disturbed by tides produced by the sun, for as yet there was no moon; and it has been suggested that one of its tidal waves rose to a height so great as to sever its connection with the earth and to fly off as the infant moon. This event may be regarded as marking the first critical period, or catastrophe if we please, in the history of our planet. The career of our satellite after its escape from the earth is not known till it attained a distance of nine terrestrial radii; after this its progress can be clearly followed. At the eventful time of parturition the earth was rotating, with a period of from two to four hours, about an axis inclined at some 11° or 12° to the ecliptic. The time which has elapsed since the moon occupied a position nine terrestrial radii distant from the earth is at least fifty-six to fifty-seven millions of years, but may have been much more. Professor Darwin's story of the moon is certainly one of the most beautiful contributions ever made by astronomy to geology, and we shall all concur with him when he says: "A theory reposing on veræ causæ, which brings into quantitative correlation the length of the present day and month, the obliquity of the ecliptic, and the inclination and eccentricity of the lunar orbit, must, I think, have strong claims to acceptance."

The majority of geologists have long hankered after a metallic nucleus for the earth, composed chiefly, by analogy with meteorites, of iron. Lord Kelvin has admitted the probable existence of some such nucleus, and lately Professor Wiechert has furnished us with arguments—"powerful" arguments, Professor Darwin terms them—in support of its existence. The interior of the earth for four-fifths of the radius is composed, according to Professor Wiechert, chiefly of metallic iron, with a density of 8.2; the outer envelope, one-fifth of the radius, or about 400 miles in thickness, consists of silicates, such as we are familiar with in igneous rocks and meteorites, and possesses a density of 3.2. It was from this outer envelope when molten that the moon was trundled off, 27 miles in depth going to its formation. The density of this material, as we have just seen, is supposed to be 3.2; the density of the moon is 3.39, a close approximation, such difference as exists being completely explicable by the comparatively low temperature of the moon.

The outer envelope of the earth which was drawn off to form the moon was, as we have seen, charged with steam and other gases under a pressure of 5,000 pounds to the square inch; but as the satellite wandered away from the parent planet this pressure continuously diminished. Under these circumstances the moon would become as explosive as a charged bomb, steam would burst forth from numberless volcanoes, and while the face of the moon might thus have acquired its existing features, the ejected material might possibly have been shot so far away from its origin as to have acquired an independent orbit. If so, we may ask whether it may not be possible that the meteorites, which sometimes descend upon our planet, are but portions of its own envelope returning to it. The facts that the average specific gravity of those meteorites which have been seen to fall is not much above 3.2, and that they have passed through a stage of fusion, are consistent with this suggestion.

SECOND CRITICAL PERIOD, "CONSISTENTIOR STATUS."

The solidification of the earth probably became completed soon after the birth of the moon. The temperature of its surface at the time of consolidation was about 1,170° C., and it was therefore still surrounded by its primitive deep atmosphere of steam and other gases. This was the second critical period in the history of the earth, the stage of the "consistentior status," the date of which Lord Kelvin would rather know than that of the Norman Conquest, though he thinks it lies between twenty and forty millions of years ago, probably nearer twenty than forty.

Now that the crust was solid there was less reason why movements of the atmosphere should be unsteady, and definite regions of high and low pressure might have been established. Under the high-pressure areas the surface of the crust would be depressed; correspondingly, under the low-pressure areas it would be raised; and thus from the first the surface of the solid earth might be dimpled and embossed.[1]

THIRD CRITICAL PERIOD—ORIGIN OF THE OCEANS.

The cooling of the earth would continuously progress, till the temperature of the surface fell to 370° C., when that part of the atmosphere which consisted of steam would begin to liquefy; then the dimples on the surface would soon become filled with superheated water, and the pools so formed would expand and deepen till they formed the oceans. This is the third critical stage in the history of the earth, dating, according to Professor Joly, from between eighty and ninety millions of years ago. With the growth of the oceans the distinction between land and sea arose—in what precise manner we may proceed to inquire. If we revert to the period of the "consistentior status," when the earth had just solidified, we shall find, according to Lord Kelvin, that the temperature continuously increased from the surface, where it was 1,170° C., down to a depth of 25 miles, where it was about 1,430° C., or 260° C. above the fusion point of the matter, forming the crust. That the crust at this depth was not molten but solid is to be explained by the very great pressure to which it was subjected—just so much pressure, indeed, as was required to counteract

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[1] It would be difficult to discuss with sufficient brevity the probable distribution of these inequalities, but it may be pointed out that the moon is possibly responsible, and that in more ways than one, for much of the existing geographical asymmetry.

the influence of the additional 260° C. Thus, if we could have reduced the pressure on the crust we should have caused it to liquefy. By restoring the pressure it would resolidify. By the time the earth's surface had cooled down to 370° C. the depth beneath the surface at which the pressure just kept the crust solid would have sunk some slight distance inward, but not sufficiently to affect our argument.

The average pressure of the primitive atmosphere upon the crust can readily be calculated by supposing the water of the existing oceans to be uniformly distributed over the earth's surface, and then by a simple piece of arithmetic determining its depth. This is found to be 1.718 miles, the average depth of the oceans being taken at 2.393 miles. Thus, the average pressure over the earth's surface immediately before the formation of the oceans was equivalent to that of a column of water 1.718 miles high on each square inch. Supposing that at its origin the ocean were all "gathered together into one place" and "the dry land appeared," then the pressure over the ocean floor would be increased from 1.718 miles to 2.393 miles, while that over those portions of the crust that now formed the land would be diminished by 1.718 miles. This difference in pressure would tend to exaggerate those faint depressions which had arisen under the primitive anticyclonic areas, and if the just solidified material of the earth's crust were set into a state of flow it might move from under the ocean into the bulgings which were rising to form the land until static equilibrium were established. Under these circumstances the pressure of the ocean would be just able to maintain a column of rock 0.886 mile in height, or ten twenty-sevenths of its own depth. It could do no more. But in order that the dry land may appear, some cause must be found competent either to lower the ocean bed the remaining seventeen twenty-sevenths of its full depth or to raise the continental bulgings to the same extent. Such a cause may, I think, be discovered in a further effect of the reduction in pressure over the continental areas. Previous to the condensation of the ocean these, as we have seen, were subjected to an atmospheric pressure equal to that of a column of water 1.718 miles in height. This pressure was contributory to that which caused the outer 25 miles of the earth's crust to become solid. It furnished, indeed, just about one-fortieth of that pressure, or enough to raise the fusion point 6° C. What, then, might be expected to happen when the continental area was relieved of this load? Plainly a liquefaction and corresponding expansion of the underlying rock.

But we will not go so far as to assert that actual liquefaction would result. All we require for our explanation is a great expansion, and this would probably follow whether the crust were liquefied or not. For there is good reason to suppose that when matter at a temperature above its ordinary fusion point is compelled into the solid state by pressure its volume is very responsive to changes, either of pressure or temperature. The remarkable expansion of liquid carbon dioxide is a case in point: 120 volumes of this fluid at −20° C. become 150 volumes at 33° C., a temperature just below the critical point. A great change of volume also occurs when the material of igneous rocks passes from the crystalline state to that of glass. In the case of diabase[1] the difference in volume of the rock in the two states at ordinary temperatures is 13 per cent. If the relief of pressure over the site of continents were accompanied by volume changes at all approaching this, the additional elevation of seventeen twenty-sevenths required to raise the land to the sea level would be accounted for.[2] How far down beneath the surface the unloading of the continents would be felt it is difficult to say, though the problem is probably not beyond the reach of mathematical analysis; if it affected an outer envelope 25 miles in thickness, a linear expansion of 4 per cent would suffice to explain the origin of ocean basins. If now we refer to the dilatation determined by Carl Barus for rise in temperature in the case of diabase, we find that between 1,093° and 1,112° C. the increase in volume is 3.3 per cent. As a further factor in deepening the ocean basins may be included the compressive effect of the increase in load over the ocean floor; this increase is equal to the pressure of a column of water 0.675 mile in height, and its effect in raising the fusion point would be 2°

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[1] C. Barus so names the material on which he experimented. Apparently the rock is a fresh dolerite without olivine.

[2] Professor Fitzgerald has been kind enough to express part of the preceding explanation in a more precise manner for me. He writes: "It would require a very nice adjustment of temperatures and pressures to work out in the simple way you state it, but what is really involved is that in a certain state diabase (and everything that changes state with a considerable change of volume) has an enormous isothermal compressibility. Although this is very enormous in the case of bodies which melt suddenly, like ice, it would also involve very great compressibilities in the case of bodies even which melted gradually, if they did so at all quickly, i. e., within a small range of temperature. What you postulate, then, is that at a certain depth diabase is soft enough to be squeezed from under the oceans, and that, being near its melting point, the small relief of pressure is accompanied by an enormous increase in volume which helped to raise the continents. Now that I have written the thing out in my own way it seems very likely. It is, anyway, a suggestion quite worthy of serious consideration, and a process that in some places must almost certainly have been in operation and maybe is still operative. Looking at it again, I hardly think it is quite likely that there is or could be much squeezing sideways of liquid or other viscous material from under one place to another, because the elastic yielding of the inside of the earth would be much quicker than any flow of this kind. This would only modify your theory, because the diabase that expands so much on the relief of pressure might be that already under the land and raising up this latter, partly by being pushed up itself by the elastic relief of the inside of the earth and partly by its own enormous expansibility near its melting point. The action would be quite slow, because it would cool itself so much by its expansion that it would have to be warmed up from below or by tidal earth squeezing or by chemical action before it could expand isothermally."

C., from which we may gain some kind of idea of the amount of compression it might produce on the yielding interior of the crust. To admit that these views are speculative will be to confess nothing, but they certainly account for a good deal. They not only give us ocean basins, but basins of the kind we want; that is, to use a crude comparison once made by the late Dr. Carpenter, basins of a tea-tray form, having a somewhat flat floor and steeply sloping sides: they also help to explain how it is that the value of gravity is greater over the ocean than over the land.

The ocean when first formed would consist of highly heated water, and this, as is well known, is an energetic chemical reagent when brought into contact with silicates like those which formed the primitive crust. As a result of its action saline solutions and chemical deposits would be formed; the latter, however, would probably be of no great thickness, for the time occupied by the ocean in cooling to a temperature not far removed from the present would probably be included within a few hundreds of years.

THE STRATIFIED SERIES.

The course of events now becomes somewhat obscure, but sooner or later the familiar processes of denudation and the deposition started into activity, and have continued acting uninterruptedly ever since. The total maximum thickness of the sedimentary deposits, so far as I can discover, appears to amount to no less than 50 miles, made up as follows:

	Feet.	
Recent and Pleistocene	4,000	Man.
Pliocene	5,000	Pithecanthropus.
Miocene	9,000	
Oligocene	12,000	
Eocene	12,000	Eutheria.
Cretaceous	14,000	
Jurassic	8,000	
Trias	13,000	Mammals.
Permian	12,000	Reptiles.
Carboniferous	24,000	Amphibia.
Devonian	22,000	Fish.
Silurian	15,000	
Ordovician	17,000	
Cambrian	16,000	Invertebrata.
Keeweenawan	50,000	
Penokee	14,000	
Huronian	18,000	

Geologists, impressed with the tardy pace at which sediments appear to be accumulating at the present day, could not contemplate this colossal pile of strata without feeling that it spoke of an almost inconceivably long lapse of time. They were led to compare its duration with the distances which intervene between the heavenly bodies; but while some chose the distance of the nearest fixed star as their unit, others were content to measure the years in terms of miles from the sun.

EVOLUTION OF ORGANISMS.

The stratified rocks were eloquent of time, and not to the geologist alone; they appealed with equal force to the biologist. Accepting Darwin's explanation of the origin of species, the present rate at which form flows to form seemed so slow as almost to amount to immutability. How vast, then, must have been the period during which by slow degrees and innumerable stages the protozoon was transformed into the man! And if we turn to the stratified column, what do we find? Man, it is true, at the summit, the oldest fossiliferous rocks 34 miles lower down, and the fossils they contain already representing most of the great classes of the Invertebrata, including Crustacea and Worms. Thus the evolution of the Vertebrata alone is known to have occupied a period represented by a thickness of 34 miles of sediment. How much greater, then, must have been the interval required for the elaboration of the whole organic world! The human mind, dwelling on such considerations as these, seems at times to have been affected by a sur-excitation of the imagination, and a consequent paralysis of the understanding, which led to a refusal to measure geological time by years at all, or to reckon by anything less than "eternities."

GEOLOGIC PERIODS OF TIME.

After the admirable address of your president last year it might be thought needless for me to again enter into a consideration of this subject; it has been said, however, that the question of geological time is like the Djinn in Arabian tales. and will irrepressibly come up again for discussion, however often it is disposed of. For my part, I do not regard the question so despondingly, but rather hope that by persevering effort we may succeed in discovering the talisman by which we may compel the unwilling Djinn into our service. How immeasurable would be the advance of our science could we but bring the chief events which it records into some relation with a standard of time!

Before proceeding to the discussion of estimates of time drawn from a study of stratified rocks let us first consider those which have been already suggested by other data. These are as follows: (1) Time which has elapsed since the separation of the earth and moon, fifty-six millions of years, minimum estimate by Prof. G. H. Darwin. (2) Since the "consistentior status," twenty to forty millions (Lord Kelvin). (3) Since the condensation of the oceans, eighty to ninety millions, maximum estimate by Prof. J. Joly.

It may be at once observed that these estimates, although independent, are all of the same order of magnitude and so far confirmatory of each other. Nor are they opposed to conclusions drawn from a study of stratified rocks; thus Sir Archibald Geikie, in his address to this section last year, affirmed that, so far as these were concerned, one hundred millions of years might suffice for their formation. There is, then, very little to quarrel about, and our task is reduced to an attempt, by a little stretching and a little paring, to bring these various estimates into closer harmony.

Professor Darwin's estimate is admittedly a minimum; the actual time, as he himself expressly states, "may have been much longer." Lord Kelvin's estimate, which he would make nearer twenty than forty millions, is founded on the assumption that since the period of the "consistentior status" the earth has cooled simply as a solid body, the transference of heat from within outwards having been accomplished solely by conduction.[1]

It may be at once admitted that there is a large amount of truth in this assumption; there can be no possible doubt that the earth reacts toward forces applied for a short time as a solid body. Under the influence of the tides it behaves as though it possessed a rigidity approaching that of steel, and under sudden blows, such as those which give rise to earthquakes, with twice this rigidity, as Professor Milne informs me. Astronomical considerations lead to the conclusion that its effective rigidity has not varied greatly for a long period of past time.

Still, while fully recognizing these facts, the geologist knows—we all know—that the crust of the earth is not altogether solid. The existence of volcanoes by itself suggests the contrary, and although the total amount of fluid material which is brought from the interior to the exterior of the earth by volcanic action may be, and certainly is, small—from data given by Professor Penck I estimate it as equivalent to a layer of rock uniformly distributed 2 mm. thick per century—yet we have every reason to believe that volcanoes are but the superficial manifestation of far greater bodies of molten material which lie concealed beneath the ground. Even the wide areas of plutonic rock, which are sometimes exposed to view over a country that has suffered long-continued denudation, are merely the upper portion of more extensive masses which lie remote from view. The existence of molten material within the earth's crust naturally awakens a suspicion that the process of cooling has not been wholly by conduction, but also to some slight extent by convection, and to a still greater extent by the bodily migration of liquid lava from the deeper layers of the crust toward the surface.

The existence of local reservoirs of molten rock within the crust is still more important in another connection—that is, in relation with the

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[1] The heat thus brought to the surface would amount to one-seventeenth of that conveyed by conduction.

supposed "average rate of increase of temperature with descent below the ground." It is doubtful whether we have yet discovered a rate that in any useful sense can be spoken of as "average." The widely divergent views of different authorities as to the presumed value of this rate may well lead to reflection. The late Professor Prestwich thought a rise of 1° F. for every 45 feet of descent below the zone of constant temperature best represented the average; Lord Kelvin in his earlier estimates has adopted a value of 1° F. for every 51 feet; the committee of this association appointed to investigate this question arrived at a rate of 1° F. for every 60 feet of descent; Mr. Clarence King has made calculations in which a rate of 1° F. for 72 feet is adopted; a reinvestigation of recorded measurements would, I believe, lead to a rate of 1° F. in 80 or 90 feet as more closely approaching the mean. This would raise Lord Kelvin's estimate to nearly fifty millions of years.

When from these various averages we turn to the observations on which they are based, we encounter a surprising divergence of extremes from the mean. Thus in the British Isles alone the rate varies from 1° F. in 34 feet to 1° F. in 92 feet, or in one case to 1° F. in 130 feet. It has been suggested, and to some extent shown, that these irregularities may be connected with differences in conductivity of the rocks in which the observations were made, or to the circulation of underground water; but many cases exist which can not be explained away in such a manner, but are suggestive of some deep-seated cause, such as the distribution of molten matter below the ground. Inspection of the accompanying map of the British Isles, on which the rates of increase in different localities have been plotted, will afford some evidence of the truth of this view. Comparatively low rates of increase are found over Wales and in the province of Leinster, districts of relatively great stability, the remnants of an island that have in all probability stood above the sea ever since the close of the Silurian period. To the north of this, as we enter a region which was subject to volcanic disturbances during the Tertiary period, the rate increases.

It is obvious that in any attempt to estimate the rate at which the earth is cooling as a solid body the disturbing influence of subterranean lakes of molten rock must as far as possible be eliminated; but this will not be effected by taking the accepted mean of observed rates of increase of temperature. Such an average is merely a compromise, and a nearer approach to a correct result will possibly be attained by selecting some low rate of increase, provided it be based on accurate observations.

It is extremely doubtful whether an area such as the British Isles, which has so frequently been the theater of volcanic activity and other subterranean disturbance, is the best fitted to afford trustworthy results. The Archæan nucleus of a continent might be expected to afford surer indications. Unfortunately, the hidden treasures of the earth are seldom buried in these regions, and bore holes in consequence have rarely been made in them. One exception is afforded by the copper-bearing district of Lake Superior, and in one case, that of the Calumet and Hecla mine, which is 4,580 feet in depth, the rate of increase, as determined by Prof. A. Agassiz, was 1° F. for every 223.7 feet. The Bohemian "horst" is a somewhat ancient part of Europe, and in the Przibram mines, which are sunk in it, the rate was 1 F. for every 126 feet of descent. In the light of these facts it would seem that geologists are by no means compelled to accept the supposed mean rate of increase of temperature with descent into the crust as affording a safe guide to the rate of cooling of a solid globe; and if the much slower rate of increase observed in the more ancient and more stable regions of the earth has the importance which is suggested for it, then Lord Kelvin's estimate of the date of the "consistentior status" may be pushed backward into a remoter past.

If, as we have reason to hope, Lord Kelvin's somewhat contracted period will yield to a little stretching, Professor Joly's, on the other hand, may take some paring. His argument, broadly stated, is as follows: The ocean consisted at first of fresh water; it is now salt, and its saltness is due to the dissolved matter that is constantly being carried into it by rivers. If, then, we know the quantity of salt which the rivers bring down each year into the sea, it is easy to calculate how many years they have taken to supply the sea with all the salt it at present contains. For several reasons it is found necessary to restrict attention to one only of the elements contained in sea salt. This is sodium. The quantity of sodium delivered to the sea every year by rivers is about 160,000,000 tons; but the quantity of sodium which the sea contains is at least ninety millions of times greater than this. The period during which rivers have been carrying sodium into the sea must therefore be about ninety millions of years. Nothing could be simpler; there is no serious flaw in the method, and Professor Joly's treatment of the subject is admirable in every way. But of course in calculations such as this everything depends on the accuracy of the data, which we may therefore proceed to discuss. Professor Joly's estimate of the amount of sodium in the ocean may be accepted as sufficiently near the truth for all practical purposes. We may therefore pass on to the other factor, the annual contribution of sodium by river water. Here there is more room for error. Two quantities must be ascertained—one the quantity of water which the rivers of the world carry into the sea, the other the quantity or proportion of sodium present in this water. The total volume of water discharged by rivers into the ocean is estimated by Sir John Murray as 6,524 cubic miles. The estimate being based on observations of 33 great rivers, although only approximate, it is no doubt sufficiently exact; at all events such alterations as it is likely to undergo will not greatly affect the final result. When, however, we pass to the last quantity to be determined, the chemical composition of average river water, we find that only a very rough estimate is possible, and this is the more unfortunate because changes in this may very materially affect our conclusions. The total quantity of river water discharged into the sea is, as we have stated, 6,524 cubic miles. The average composition of this water is deduced from analyses of 19 great rivers, which altogether discharge only 488 cubic miles, or 7.25 per cent of the whole. The danger in using this estimate is twofold; in the first place, 7.25 is too small a fraction from which to argue to the remaining 92.75 per cent, and, next, the rivers which furnish it are selected rivers, i. e., they are all of large size. The effect of this is that the drainage of the volcanic regions of the earth is not sufficiently represented, and it is precisely this drainage which is richest in sodium salts. The lavas and ashes of active volcanoes rapidly disintegrate under the energetic action of various acid gases, and among volcanic exhalations sodium chloride has been especially noticed as abundant. Consequently, we find that while the proportion of sodium in Professor Joly's average river water is only 5.73 per million, in the rivers of the volcanic island of Hawaii it rises to 24.5 per million (Walter Maxwell, Lavas and Soils of the Hawaiian Islands, p. 170). No doubt the area occupied by volcanoes is trifling compared with the remaining land surface. On the other hand, the majority of volcanoes are situated in regions of copious rainfall, of which they receive a full share, owing to their mountainous form. Much of the fallen rain percolates through the porous material of the cone, and, richly charged with alkalies, finds its way by underground passages toward the sea, into which it sometimes discharges by submarine springs.

Again, several considerations lead to the belief that the supply of sodium to the ocean has proceeded, not at a uniform, but at a gradually diminishing rate. The rate of increase of temperature with descent into the crust has continuously diminished with the flow of time, and this must have had its influence on the temperature of springs, which furnish an important contribution to river water. The significance of this consideration may be judged from the composition of the water of geysers. Thus Geyser, in Iceland, contains 884 parts of sodium per million, or nearly one hundred and sixty times as much as Sir John Murray estimates is present in average river water. A mean of the analyses of six geysers in different parts of the world gives 400 parts of sodium per million, existing partly as chloride, but also as sulphate and carbonate.

It should not be overlooked that the present is a calm and quiet epoch in the earth's history, following after a time of fiery activity.

More than once, indeed, has the past been distinguished by unusual manifestations of volcanic energy, and these must have had some effect upon the supply of sodium to the ocean. Finally, although the existing ocean water has apparently but slight effect in corroding the rocks which form its bed, yet it certainly was not inert when its temperature was not far removed from the critical point. Water begins to exert a powerful destructive action on silicates at a temperature of 180° C., and during the interval occupied in cooling from 370° to 180° C. a considerable quantity of sodium may have entered into solution.

A review of the facts before us seems to render some reduction in Professor Joly's estimate imperative. A precise assessment is impossible, but I should be inclined myself to take off some ten or thirty millions of years.

We may next take the evidence of the stratified rocks. Their total maximum thickness is, as we have seen, 265,000 feet, and consequently if they accumulated at the rate of 1 foot in a century, as evidence seems to suggest, more than twenty-six millions of years must have elapsed during their formation.

OBSCURE CHAPTER IN THE EARTH'S HISTORY.

Before discussing the validity of the argument on which this last result depends, let us consider how far it harmonizes with previous ones. It is consistent with Lord Kelvin's and Professor Darwin's, but how does it accord with Professor Joly's? Supposing we reduce his estimate to fifty-five millions; what was the earth doing during the interval between the period of fifty-five millions of years ago and that of only twenty-six and one-half millions of years ago, when, it is presumed, sedimentary rocks commenced to be formed? Hitherto we have been able to reason on probabilities; now we enter the dreary region of possibilities, and open that obscure chapter in the history of the earth previously hinted at. For there are many possible answers to this question. In the first place the evidence of the stratified rocks may have been wrongly interpreted, and two or three times the amount of time we have demanded may have been consumed in their formation. This is a very obvious possibility, yet again our estimate concerning these rocks may be correct, but we may have erroneously omitted to take into account certain portions of the Archæan complex, which may represent primitive sedimentary rocks, formed under exceptional conditions, and subsequently transformed under the influence of the internal heat of the earth. This, I think, would be Professor Bonney's view. Finally Lord Kelvin has argued that the life of the sun as a luminous star is even more briefly limited than that of our oceans. In such a case if our oceans were formed fifty-five millions of years ago it is possible that after a short existence as almost boiling water they grew colder and colder till they became covered with thick ice and moved only in obedience to the tides. The earth, frozen and dark except for the red glow of her volcanoes, waited the coming of the sun, and it was not till his growing splendor had banished the long night that the cheerful sound of running waters was heard again in our midst. Then the work of denudation and deposition seriously recommenced, not to cease till the life of the sun is spent. Thus the thickness of the stratified series may be a measure rather of the duration of sunlight than of the period which has elapsed since the first formation of the ocean. It may have been so—we can not tell—but it may be fairly urged that we know less of the origin, history, and constitution of the sun than of the earth itself, and that, for aught we can say to the contrary, the sun may have been shining on the just-formed ocean as cheerfully as he shines to-day.

TIME REQUIRED FOR THE EVOLUTION OF THE LIVING WORLD.

But, it will be asked, how far does a period of twenty-six millions satisfy the demands of biology? Speaking only for myself, although I am aware that eminent biologists are not wanting who share this opinion, I answer, amply. But it will be exclaimed, surely there are "comparisons in things." Look at Egypt, where more than four thousand years since the same species of man and animals lived and flourished as to-day. Examine the frescoes and study the living procession of familiar forms they so faithfully portray, and then tell us, how comes it about that from changes so slow as to be inappreciable in the lapse of forty centuries you propose to build up the whole organic world in the course of a mere twenty-six millions of years? To all which we might reply that even changeless Egypt presents us with at least one change—the features of the ruling race are to-day not quite the same as those of the Pharaohs. But putting this on one side, the admitted constancy in some few common forms proves very little, for so long as the environment remains the same natural selection will conserve the type, and, so far as we are able to judge, conditions in Egypt have remained remarkably constant for a long period.

Change the conditions, and the resulting modification of the species becomes manifest enough; and in this connection it is only necessary to recall the remarkable mutations observed and recorded by Professor Weldon in the case of the crabs in Plymouth Harbor. In response to increasing turbidity of the sea water these crabs have undergone or are undergoing a change in the relative dimensions of the carapace, which is persistent, in one direction, and rapid enough to be determined by measurements made at intervals of a few years.

Again animals do not all change their characters at the same rate; some are stable, in spite of changing conditions, and these have been cited to prove that none of the periods we look upon as probable, not twenty-five, not a hundred millions of years, scarce any period short of eternity, is sufficient to account for the evolution of the living world. If the little tongue-shell, *Lingula*, has endured with next to no perceptible change from the Cambrian down to the present day, how long, it is sometimes inquired, would it require for the evolution of the rest of the animal kingdom? The reply is simple. The cases are dissimilar, and the same record which assures us of the persistency of the *Lingula* tells us in language equally emphatic of the course of evolution which has led from the lower organisms upward to man. In recent and Pleistocene deposits the relics of man are plentiful. In the latest Pliocene they have disappeared, and we encounter the remarkable form *Pithecanthropus*. As we descend into the Tertiary systems the higher mammals are met with, always sinking lower and lower in the scale of organization as they occur deeper in the series, till in the Mesozoic deposits they have entirely disappeared, and their place is taken by the lower mammals, a feeble folk, offering little promise of the future they were to inherit. Still lower, and even these are gone; and in the Permian we encounter reptiles and the ancestors of reptiles, probably ancestors of mammals, too; then into the Carboniferous, where we find amphibians, but no true reptiles; and next into the Devonian, where fish predominate, after making their earliest appearance at the close of the Silurian times; thence downward, and the vertebrata are no more found—we trace the evolution of the invertebrata alone. Thus the orderly procession of organic forms follows in precisely the true phylogenetic sequence: invertebrata first, then vertebrates, at first fish, then amphibia, next reptiles, soon after mammals, of the lowlier kinds first, of the higher later, and these in increasing complexity of structure till we finally arrive at man himself. While the living world was thus unfolding into new and nobler forms, the immutable *Lingula* simply perpetuated its kind. To select it or other species equally sluggish, as the sole measure of the rate of biologic change would seem as strange a proceeding as to confound the swiftness of a river with the stagnation of the pools that lie beside its banks. It is occasionally objected that the story we have drawn from the paleontological record is mere myth or is founded only on negative evidence. Cavils of this kind prove a double misapprehension, partly as to the facts, partly as to the value of negative evidence, which may be as good in its way as any other kind of evidence.

Geologists are not unaware of the pitfalls which beset negative evidence, and they do not conclude from the absence of fossils in the rocks which underlie the Cambrian that pre-Cambrian periods were devoid of life; on the contrary, they are fully persuaded that the seas of those times were teeming with a rich variety of invertebrate forms. How is it that, with the exception of some few species found in beds immediately underlying the Cambrian, these have left behind no vestige of their existence? The explanation does not lie in the nature of the sediments, which are not unfitted for the preservation of fossils, nor in the composition of the then existing sea water, which may have contained quite as much calcium carbonate as occurs in our present oceans; and the only plausible supposition would appear to be that the organisms of that time had not passed beyond the stage now represented by the larvæ of existing invertebrata, and consequently were either unprovided with skeletons, or at all events with skeletons durable enough for preservation. If so, the history of the earlier stages of the evolution of the invertebrata will receive no light from paleontology; and no direct answer can be expected to the question whether, eighteen or nineteen millions of years being taken as sufficient for the evolution of the vertebrata, the remaining available eight millions would provide for that of the invertebrate classes which are represented in the lowest Cambrian deposits. On a priori grounds there would appear to be no reason why it should not. If two millions of years afforded time enough for the conversion of fish into amphibians, a similar period should suffice for the evolution of trilobites from annelids, or of annelids from trochospheres. The step from gastrulas to trochospheres might be accomplished in another two millions, and two millions more would take us from gastrulas through morulas to protozoa.

As things stand, biologists can have nothing to say either for or against such a conclusion; they are not at present in a position to offer independent evidence; nor can they hope to be so until they have vastly extended those promising investigations which they are only now beginning to make into the rate of the variation of species.

UNEXPECTED ABSENCE OF THERMAL METAMORPHOSIS IN ANCIENT ROCKS.

Two difficulties now remain for discussion—one based on theories of mountain chains, the other on the unaltered state of some ancient sediments. The latter may be taken first. Professor van Hise writes as follows regarding the pre-Cambrian rocks of the Lake Superior district: "The Penokee series furnishes an instructive lesson as to the depth to which rocks may be buried and yet remain but slightly affected by metamorphosis. The series itself is 14,000 feet thick. It was covered before being upturned with a great thickness of Keweenaw rock. This series at the Montreal River is estimated to be 50,000 feet thick. Adding to this the known thickness of the Penokee series, we have a thickness of 64,000 feet. * * * The Penokee rocks were then buried to a great depth, the exact amount depending upon their horizon and upon the stage in Keweenaw time, where the tilting and erosion, which brought them to the surface, commenced.

"That the synclinal trough of Lake Superior began to form before the end of the Keweenaw period, and consequently that the Penokee rocks were not buried under the full succession is more than probable. However, they must have been buried to a great depth—at least several miles—and thus subjected to high pressure and temperature, notwithstanding which they are comparatively unaltered."[1]

I select this example because it is one of the best instances of a difficulty that occurs more than once in considering the history of sedimentary rocks. On the supposition that the rate of increment of temperature with descent is 1° F. for every 84 feet, or 1° C. for every 150 feet, and that it was no greater during these early Penokee times, then at a depth of 50,000 feet the Penokee rocks would attain a temperature of nearly 333° C., and since water begins to exert powerful chemical action at 180° C. they should, on the theory of a solid cooling globe, have suffered a metamorphosis sufficient to obscure their resemblance to sedimentary rocks. Either, then, the accepted rate of downward increase of temperature is erroneous or the Penokee rocks were never depressed in the place where they are exposed to observation to a depth of 50,000 feet. Let us consider each alternative, and in the first place let us apply the rate of temperature increment determined by Professor Agassiz in this very Lake Superior district. It is 1° C. for every 402 feet, and twenty-five millions of years ago, or about the time when we may suppose the Penokee rocks were being formed, it would be 1° C. for every 305.5 feet, with a resulting temperature at a depth of 50,000 feet of 163° C. only. Thus the admission of a very low rate of temperature increment would meet the difficulty; but, on the other hand, it would involve a period of several hundreds of millions of years for the age of the "consistentior status," and thus greatly exceed Professor Joly's maximum estimate of the age of oceans. We may therefore turn to the second alternative. As regards this it is by no means certain that the exposed portion of the Penokee series ever was depressed 50,000 feet. The beds lie in a synclinal, the base of which indeed may have sunk to this extent, and entered a region of metamorphosis; but the only part of the system that lies exposed to view is the upturned margin of the synclinal, and as to this it would seem impossible to make any positive assertion as to the depth to which it may or may not have been depressed. To keep an open mind on the question seems our only course for the present, but difficulties like this offer a promising field for investigation.

THE FORMATION OF MOUNTAIN RANGES.

It is frequently alleged that mountain chains can not be explained on the hypothesis of a solid earth cooling under the conditions and for the period we have supposed. This is a question well worthy of consideration, and we may first endeavor to picture to ourselves the conditions under which mountain chains arise. The floor of the ocean lies

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[1] Tenth Annual Report U. S. Geological Survey, 1888–89, p. 457.

at an average depth of 2,000 fathoms below the land, and is maintained at a constant temperature, closely approaching 0° C., by the passage over it of cold water creeping from the polar regions. The average temperature of the surface of the land is above zero, but we can afford to disregard the difference in temperature between it and the ocean floor and may take them both at zero. Consider next the increase of temperature with descent, which occurs beneath the continents. At a depth of 13,000 feet, or at same depth as the ocean floor, a temperature of 87° C. will be reached on the supposition that the rate of increase is 1° C. for 150 feet, while with the usually accepted rate of 1° C. for 108 feet it would be 120° C. But at this depth the ocean floor, which is on the same spherical surface, is at 0° C. Thus surfaces of equal temperature within the earth's crust will not be spherical, but will rise or fall beneath an imaginary spherical or spheroidal surface according as they occur beneath the continents or the oceans. No doubt at some depth within the earth the departure of isothermal surfaces from a spheroidal form will disappear; but considering the great breadth both of continents and oceans this depth must be considerable, possibly even 40 or 50 miles. Thus the subcontinental excess of temperature may make itself felt in regions where the rocks still retain a high temperature, and are probably not far removed from the critical fusion point. The effect will be to render the continents mobile as regards the ocean floor, or, vice versa, the ocean floor will be stable compared with the continental masses. Next it may be observed that the continents pass into the bed of the ocean by a somewhat rapid flexure, and that it is over this area of flexure that the sediments denuded from the land are deposited. Under its load of sediment the sea floor sinks down, subsiding slowly, at about the same rate as the thickness of sediment increases; and, whether as a consequence or a cause or both, the flexure marking the boundary of land and sea becomes more pronounced. A compensating movement occurs within the earth's crust, and solid material may flow from under the subsiding area in the direction of least resistance, possibly toward the land. At length when some 30,000 or 40,000 feet of sediment have accumulated in a basin-like form, or, according to our reckoning, after the lapse of three or four millions of years, the downward movement ceases, and the mass of sediment is subjected to powerful lateral compression, which, bringing its borders into closer proximity by some 10 or 30 miles, causes it to rise in great folds high into the air as a mountain chain.

It is this last phase in the history of mountain making which has given geologists more cause for painful thought than probably any other branch of their subject, not excluding even the age of the earth. It was at first imagined that during the flow of time the interior of the earth lost so much heat, and suffered so much contraction in consequence, that the exterior, in adapting itself to the shrunken body, was compelled to fit it like a wrinkled garment. This theory, indeed, enjoyed a happy existence till it fell into the hands of mathematicians, when it fared very badly, and now lies in a pitiable condition neglected of its friends.[1]

For it seemed proved to demonstration that the contraction consequent on cooling was wholly, even ridiculously, inadequate to explain the wrinkling. But when we summon up courage to inquire into the data on which the mathematical arguments are based, we find that they include several assumptions the truth of which is by no means self-evident. Thus it has been assumed that the rate at which the fusion point rises with increased pressure is constant and follows the same law as is deduced from experiments made under such pressures as we can command in our laboratories down to the very center of the earth, where the pressures are of an altogether different order of magnitude; so with a still more important coefficient, that of expansion, our knowledge of this quantity is founded on the behavior of rocks heated under ordinary atmospheric pressure, and it is assumed that the same coefficient as is thus obtained may be safely applied to material which is kept solid, possibly near the critical point, under the tremendous pressure of the depths of the crust. To this last assumption we owe the terrible bogies that have been conjured out of "the level of no strain." The depth of this as calculated by the Rev. O. Fisher is so trifling that it would be passed through by all very deep mines. Mr. C. Davison, however, has shown that it will lie considerably deeper, if the known increase of the coefficient of expansion with rise of temperature be taken into account. It is possible, it is even likely, that the coefficient of expansion becomes vastly greater when regions are entered where the rocks are compelled into the solid state by pressure. So little do we actually know of the behavior of rock under these conditions that the geologist would seem to be left very much to his own devices; but it would seem there is one temptation he must resist—he may not take refuge in the hypothesis of a liquid interior.

We shall boldly assume that the contraction at some unknown depth in the interior of the earth is sufficient to afford the explanation we seek. The course of events may then proceed as follows: The contraction of the interior of the earth consequent on its loss of heat causes the crust to fall upon it in folds, which rise over the continents and sink under the oceans, and the flexure of the area of sedimentation is partly a consequence of this folding, partly of overloading. By the time a depression of some 30,000 or 40,000 feet has occurred along the ocean border the relation between continents and oceans has become unstable, and readjustment takes place, probably by a giving way of the continents, and chiefly along the zone of greatest weakness, i. e., the area of sedimentation, which thus becomes the zone of mountain

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[1] With some exceptions, notably Mr. C. Davison, a consistent supporter of the theory of contraction.

building. It may be observed that at great depths readjustment will be produced by a slow flowing of solid rock, and it is only comparatively near the surface, 5 or 10 miles at the most below, that failure of support can lead to sudden fracture and collapse; hence the comparatively superficial origin of earthquakes.

Given a sufficiently large coefficient of expansion—and there is much to suggest its existence (vide, p. 296)—and all the phenomena of mountain ranges become explicable; they begin to present an appearance that invites mathematical treatment; they inspire us with the hope that from a knowledge of the height and dimensions of a continent and its relations to the bordering ocean we may be able to predict when and where a mountain chain should arise, and the theory which explains them promises to guide us to an interpretation of those world-wide unconformities which Suess can only account for by a transgression of the sea. Finally it relieves us of the difficulty presented by mountain formation in regard to the estimated duration of geological time.

INFLUENCE OF VARIATIONS IN THE ECCENTRICITY OF THE EARTH'S ORBIT.

This may perhaps be the place to notice a highly interesting speculation which we owe to Professor Blytt, who has attempted to establish a connection between periods of readjustment of the earth's crust and variations in the eccentricity of the earth's orbit. Without entering into any discussion of Professor Blytt's methods, we may offer a comparison of his results with those that follow from our rough estimate of 1 foot of sediment accumulated in a century.

Table showing the time that has elapsed since the beginning of the systems in the first column, as reckoned from thickness of sediment in the second column, and by Professor Blytt in the third.

Period.	Years.	Years.
Eocene	4,200,000	3,250,000
Oligocene	3,000,000	1,810,000
Miocene	1,800,000	1,160,000
Pliocene	900,000	700,000
Pleistocene	400,000	350,000

It is now time to return to the task, too long postponed, of discussing the data from which we have been led to conclude that a probable rate at which sediments have accumulated in places where they attain their maximum thickness is 1 foot per century.

RATE OF DEPOSITION OF SEDIMENT.

We owe to Sir Archibald Geikie a most instructive method of estimating the existing rate at which our continents and islands are being washed into the sea by the action of rain and rivers. By this we find that the present land surface is being reduced in height to the extent, on an average, of one twenty-four hundredth foot yearly (according to Professor Penck, one thirty-six hundredth foot). If the material removed from the land were uniformly distributed over an area equal to that from which it had been derived, it would form a layer of rock one twenty-four hundredth foot thick yearly, i. e., the rates of denudation and deposition would be identical. But the two areas, that of denudation and that of deposition, are seldom or never equal, the latter as a rule being much the smaller. Thus the area of that part of North America which drains into the Gulf of Mexico measures 1,800,000 square miles, the area over which its sediments are deposited is, so far as I can gather from Professor Agassiz's statements, less than 180,000 square miles, while Mr. McGee estimates it at only 100,000 square miles. Using the largest number, the area of deposition is found to measure one-tenth the area of denudation; the average rate of deposition will therefore be ten times as great as the rate of denudation, or one two hundred and fortieth foot may be supposed to be uniformly distributed over the area of sedimentation in the course of a year. But the thickness by which we have measured the strata of our geological systems is not an average but a maximum thickness; we have therefore to obtain an estimate of the maximum rate of deposition. If we assume the deposited sediments to be arranged somewhat after the fashion of a wedge, with the thin end seaward, then twice the average would give us the maximum rate of deposition; this would be 1 foot in one hundred and twenty years. But the sheets of deposited sediment are not merely thicker toward the land, thinner toward the sea, they also increase in thickness toward the rivers in which they have their source, so that a very obtuse-angled cone, or, better, the down-turned bowl of a spoon, would more nearly represent their form. This form tends to disappear under the action of waves and currents, but a limit is set to this disturbing influence by the subsidence which marks the region opposite the mouth of a large river. By this the strata are gradually let downward, so that they come to assume the form of the bowl of a spoon turned upward. Thus a further correction is necessary if we are to arrive at a fair estimate of the maximum rate of deposition. Considering the very rapid rate at which our ancient systems diminish in thickness when traced in all directions from the localities where they attain their maximum, it would appear that this correction must be a large one. If we reduce our already corrected estimate by one-fifth, we arrive at a rate of 1 foot of sediment deposited in a century.

No doubt this value is often exceeded. Thus in the case of the Mississippi River the bar of the Southwest Pass advanced between the years 1838 and 1874 a distance of over 2 miles, covering an area 2.2 miles in width with a deposit of sediment 80 feet in thickness; outside the bar, where the sea is 250 feet in depth, sediment accumulates, according to Messrs. Humphreys and Abbot, at a rate of 2 feet yearly. It is quite possible, indeed it is very likely, that some of our ancient strata have been formed with corresponding rapidity. No gravel or coarse sand is deposited over the Mississippi delta. Such material is not carried farther seaward than New Orleans. Thus the vast sheets of conglomerate and sandstone which contribute so largely to some of our ancient systems, such as the Cambrian, Old Red Sandstone, Millstone Grit, and Coal Measures, must have accumulated under very different conditions, conditions for which it is not easy to find a parallel; but in any case these deposits afford evidence of very rapid accumulation.

These considerations will not tempt us, however, to modify our estimate of 1 foot in a century; for though in some cases this rate may have been exceeded, in others it may not have been nearly attained.

Closely connected with the rate of deposition is that of the changing level of land and sea; in some cases, as in the Wealden delta, subsidence and deposition appear to have proceeded with equal steps, so that we might regard them as transposable terms. It would, therefore, prove of great assistance if we could determine the average rate at which movements of the ground are proceeding; it might naturally be expected that the accurate records kept by tidal gauges in various parts of the world would afford us some information on this subject; and no doubt they would, were it not for the singular misbehavior of the sea, which does not maintain a constant level, its fluctuations being due, according to Professor Darwin, to the irregular melting of ice in the polar regions. Of more immediate application are the results of Herr L. Holmström's observations in Scandinavia, which prove an average rise of the peninsula at the rate of 3 feet in a century to be still in progress; and Mr. G. K. Gilbert's measurements in the Great Lake district of North America, which indicate a tilting of the continent at the rate of 3 inches per 100 miles per century. But while measurements like these may furnish us with some notion of the sort of speed of these changes, they are not sufficient even to suggest an average; for this we must be content to wait till sufficient tidal observations have accumulated, and the disturbing effect of the inconstancy of the sea level is eliminated.

It may be objected that in framing our estimate we have taken into account mechanical sediments only, and ignored others of equal importance, such as limestone and coal. With regard to limestone, its thickness in regions where systems attain their maximum may be taken as negligible; nor is the formation of limestone necessarily a slow process. The successful experiments of Dr. Allan, cited by Darwin, prove that reef-building corals may grow at the astonishing rate of 6 feet in height per annum.

In respect of coal there is much to suggest that its growth was rapid. The Carboniferous period well deserves its name, for never before, never since, have carbonaceous deposits accumulated to such a remarkable thickness or over such wide areas of the earth's surface. The explanation is doubtless partly to be found in favorable climatal conditions, but also, I think, in the youthful energy of a new and overmastering type of vegetation, which then for the first time acquired the dominion of the land. If we turn to our modern peat bogs, the only carbonaceous growths available for comparison, we find from data given by Sir A. Geikie that a fairly average rate of increase is 6 feet in a century, which might perhaps correspond to 1 foot of coal in the same period.

The rate of deposition has been taken as uniform through the whole period of time recorded by stratified rocks; but lest it should be supposed that this involves a tacit admission of uniformity, I hasten to explain that in this matter we have no choice. We may feel convinced that the rate has varied from time to time, but in what direction or to what extent it is impossible to conjecture. That the sun was once much hotter is probable, but equally so that at an earlier period it was much colder; and even if in its youth all the activities of our planet were enhanced this fact might not affect the maximum thickness of deposits. An increase in the radiation of the sun, while it would stimulate all the powers of subaerial denudation, would also produce stronger winds and marine currents. Stronger currents would also result from the greater magnitude and frequency of the tides, and thus while larger quantities of sediment might be delivered into the sea they would be distributed over wider areas, and the difference between the maximum and average thickness of deposits would consequently be diminished. Indications of such a wider distribution may perhaps be recognized in the Paleozoic systems. Thus we are compelled to treat our rate of deposition as uniform, notwithstanding the serious error this may involve.

The reasonableness of our estimate will perhaps best appear from a few applications. Fig. 2 is a chart, based on a map by De Lapparent, representing the distribution of land and sea over the European area during the Cambrian period. The strata of this system attain their maximum thickness of 12,000 feet in Merionethshire, Wales. They rapidly thin out northward, and are absent in Anglesey; scarcely less rapidly toward Shropshire, where they are 3,000 feet thick; still a little less rapidly toward the Malverns, where they are only 800 feet thick, and most slowly toward St. Davids Head, where they are 7,400 feet thick. The Cambrian rocks of Wales were in all probability the deposits of a river system which drained some vanished land once situated to the west. How great was the extent of this land none can say. Some geologists imagine it to have obliterated the whole or greater part of the North Atlantic Ocean. For my part I am content with a somewhat large island. What area of this island, we may ask, would suffice to supply the Cambrian sediments of Wales and Shropshire? Admitting that the area of denudation was ten times as large as the area of deposition, its dimensions are indicated by the figure *a b c d* on the chart. This evidently leaves room enough on the island to furnish all the other deposits which are distributed along the western shores of the Cambrian Sea, while those on the east are amply provided for by that portion of the European Continent which then stood above water.

If 1 foot in a century be a quantity so small as to disappoint the imagination of its accustomed exercise, let us turn to the Cambrian succession of Scandinavia, where all the zones recognized in the British series are represented by a column of sediment 290 feet in thickness. If 1,600,000 years be a correct estimate of the duration of Cambrian time, then each foot of the Scandinavian strata must have occupied 5,513 years in its formation. Are these figures sufficiently inconceivable?

In the succeeding system (that of the Ordovician) the maximum thickness is 17,000 feet. Its deposits are distributed over a wider area than the Cambrian, but they also occupied longer time in their formation; hence the area from which they were derived need not necessarily have been larger than that of the preceding period.

Great changes in the geography of our area ushered in the Silurian system. Its maximum thickness is found over the lake district and amounts to 15,000 feet, but in the little island of Gothland, where all the subdivisions of the system from the Landovery to the Upper Ludlow occur in complete sequence, the thickness is only 208 feet. In Gothland, therefore, according to our computation, the rate of accumulation was 1 foot in 7,211 years.

With this example we must conclude, merely adding that the same story is told by other systems and other countries, and that so far as my investigations have extended I can find no evidence which would suggest an extension of the estimate I have proposed. It is but an estimate, and those who have made acquaintance with "estimates" in the practical affairs of life know how far this kind of computation may guide us to or from the truth.

This address is already unduly long, and yet not long enough for the magnitude of the subject of which it treats. As we glance backward over the past we see catastrophism yield to uniformitarianism, and this to evolution, but each as it disappears leaves behind some precious residue of truth. For the future of our science our ambition is that which inspired the closing words of your last president's address, that it may become more experimental and exact. Our present watchword is Evolution. May our next be Measurement and Experiment, Experiment and Measurement.

FIG. 1.—DISTRIBUTION OF RATES OF INCREASE OF TEMPERATURE, WITH DESCENT.

The rates taken from "British Association Report," except in south of Ireland.

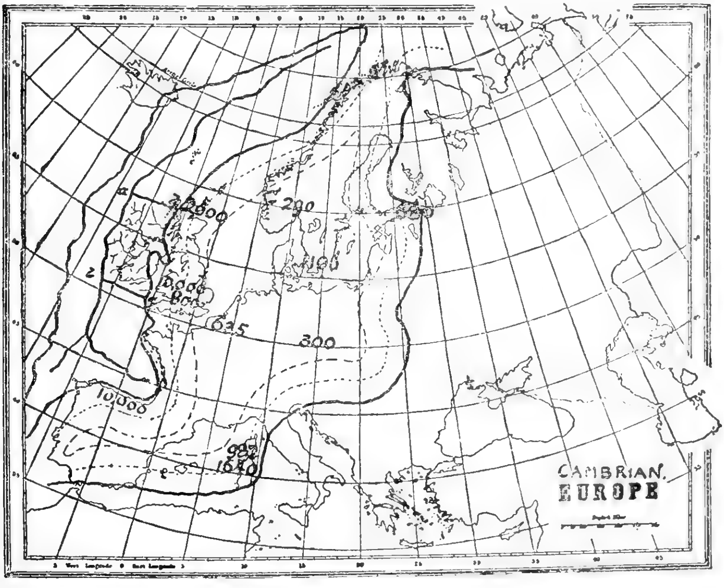

FIG. 2.—DISTRIBUTION OF LAND AND SEA, AND OF THICKNESS OF DEPOSITS OF CAMBRIAN SYSTEM.

Dotted lines indicate distances of 100 and 200 miles from shore.

PROGRESS IN PHYSICS IN THE NINETEENTH CENTURY.[1]

By Professor MENDENHALL, Ph. D., D. Sc., LL. D.

On January 7, 1610, Galileo, turning his telescope toward Jupiter, was the first to see the beautiful system of that planet in which the universe is epitomized. He had already studied the variegated surface of the moon and he had seen the spots upon the sun. A little later, in spite of the feeble power of his instrument, he had discovered that the sun rotates upon an axis, and something of the wonderful nature of the planet Saturn had been revealed to him. The overwhelming evidence thus afforded of the truth of the hypothesis of Copernicus made him its chief exponent. The time had come for man to know, as he had never known or even dreamed of before, his true relation to the universe of which he was so insignificant a part. In a single year nearly all of these capital discoveries were made. It was truly an era of intellectual expansion; never before and never since has man's intellectual horizon enlarged with such enormous rapidity. One needs little imagination to share with this ardent philosopher the enthusiasm of the moment when, because some, fearing the evidence of their senses, refused to look through the slender tube, he wrote to Kepler: "Oh, my dear Kepler, how I wish we could have one hearty laugh together. * * * Why are you not here? What shout of laughter we should have at this glorious folly!"

Galileo died in 1642, and in the same year Newton was born. When 24 years old he "began to think of gravity extending to the orb of the moon," and before the end of the century he had discovered and established the great law of universal gravitation. Thus, at the end of the seventeenth century the foundations of modern physics were in place. During the eighteenth century they were much built upon; but it is the nineteenth that has witnessed not only the greatest advance in detail, but the most important generalizations made since the time of Galileo and Newton.

In endeavoring to present to the intelligent but perhaps unscientific reader a brief review of the accomplishments of this "wonderful

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century" in the domain of physics one must not attempt more than an outline of greater events, and it will be convenient to arrange them under the several principal subdivisions of the science according to the usually accepted classification.

HEAT.

Although more than one philosopher of the seventeenth and eighteenth centuries suggested the identity of heat and molecular motion, the impression made was not lasting, and up to very near the beginning of the nineteenth century the caloric theory was accepted almost without dispute. This theory implied that heat was a subtile fluid, definite quantities of which were added to or subtracted from material substances when they became hot or cold. As carefully conducted experiments seemed to show that a body weighed no more or no less when hot than when cold, it was necessary to attribute to this fluid called caloric the mysterious property of "imponderability;" that is, unlike all forms of ordinary matter, it possessed no weight. To avoid calling it matter it was by many classed, with light, electricity, and magnetism, as one of the imponderable agents. Various other properties were attributed to caloric, necessary to the reasonable explanation of a steadily increasing array of experimental facts. It was declared to be elastic, its particles being mutually self-repellant. It was thought to attract ordinary matter, and an ingenious theory of caloric was constructed, modeled upon Newton's famous but erroneous corpuscular theory of light. During the latter part of the eighteenth century Joseph Black, professor in the universities of Glasgow and Edinburgh, developed his theory of latent heat, which, although founded upon a false notion of the nature of heat, was a most important contribution to science. The downfall of the caloric theory must be largely credited to the work of a famous American who published the results of his experiments just at the close of the eighteenth century.

Benjamin Thompson, known as Count Rumford, was born in the town of Woburn, Mass., in 1753. His inclination toward physical experimentation was strong in his early youth, and he received much instruction and inspiration from the lectures of Prof. John Winthrop, of Harvard College, some of which he was enabled to attend under trying conditions. Having received special official consideration by appointment to office under one of the colonial governors, he was accused at the breaking out of the Revolutionary war of a leaning toward Toryism, and was thus prevented from making his career among his own people. At the age of 22 years he fled to England, returning to America only for a brief period in command of a British regiment. In England he soon became eminent as an experimental philosopher, and in 1778 became a Fellow of the Royal Society. He afterwards entered the service of the Elector of Bavaria, by whom he was made a count of the Holy Roman Empire. In 1799 he returned to London and founded the "Royal Institution," which was destined during the next hundred years to surpass all other foundations in the richness and importance of its contributions to physical science. It was while at Munich that Rumford made his famous experiments in the nature of heat, to which he had been led by observing the great amount of heat generated in the boring of cannon. Finding that he was able to make a considerable quantity of water actually boil by the heat generated by a blunt boring tool, he concluded that the supply of heat from such a source was practically inexhaustible and that it could be generated continuously if only the motion of the tool under friction was kept up. He declared that anything which could thus be produced without limitation by an insulated body or system of bodies could not possibly be a material substance, and that under the circumstances of the experiment the only thing that was or could be thus continuously communicated was motion.

Count Rumford's conclusions were not accepted for a long time. Davy, the brilliant professor and eloquent lecturer at the newly established Royal Institution, espoused the mechanical theory of heat, and made the striking experiment of melting two pieces of ice by rubbing them together remote from any source of heat. His contemporary, Thomas Young, who overturned Newton's corpuscular theory of light and showed that it was a wave phenomenon, also advocated Rumford's notion of the nature of heat; but even among physicists of high rank it had made little headway as late as the middle of the nineteenth century. In the eighth edition of the Encyclopædia Britannica, published in 1856, the immediate predecessor of the current issue, heat is defined as a "material agent of a peculiar nature, highly attenuated." And this in spite of the fact that previous to that date the mechanical theory had been completely proved by the labors of Mayer, Joule, Helmholtz, and William Thomson (Lord Kelvin). By these men a solid foundation for the theory had been found in a great physical law of such importance that it is justly considered to be the most far-reaching generalization in natural philosophy since the time of Newton. Some account of this law and its discovery will be given later in this paper.

Among the most important of the century's contributions to our knowledge of heat must be included the work of Fourier, as embodied in his Theorie Analytique de la Chaleur, published in 1822. Joseph Fourier was born in 1768 and died in 1830. He belonged to that splendid group of philosophers of which the French nation may always be proud, whose work constitutes a large part of the luster of intellectual France during her most brilliant period, the later years of the eighteenth and the earlier years of the nineteenth century. His contemporaries included such men as Laplace, Arago, Lagrange, Fresnel, and Carnot. Fourier wrote especially of the movement of heat in solids, and as his thesis depended in no way on the nature of heat it will always be regarded as a classic. His assumption that conductivity was independent of temperature was shortly proved to be erroneous, but his general argument and conclusions were not greatly affected by this discovery. His work is one of the most beautiful examples yet produced of the application of mathematics to physical research, and mathematical and physical sciences were equally enriched by it. In its broader aspects his law of conduction includes the transfer of electricity in good conductors and is the real basis of Ohm's law.

One of the most skillful and successful experimenters in heat was also a Frenchman, Henri Victor Regnault (1810–1878). He greatly improved the construction and use of the thermometer, and was the first to discover that the indications of an air thermometer and one of mercury did not exactly agree, because they did not expand in the same degree for equal increases of temperature. His most important work was on the expansion of gases, vapor pressure, specific heat of water, etc., and for careful, patient measuring he had a positive genius. Until he proved the contrary it had been assumed that all gases had the same coefficient of expansion, and Boyle's law that the volume of a gas was inversely proportional to its pressure had not been questioned. His tables of the elastic force of steam have been of immense practical value, but his studies of the expansion of gases are of greater interest, because they have pointed the way to one of the most important accomplishments of the century, the liquefaction of all known gases.

During the earlier years of this century it was the custom to consider vapors and gases as quite distinct forms of matter. Vapors always came, by evaporation, from liquids and could always be "condensed" or reduced to the liquid form without difficulty, but it was not thought possible to liquefy the so-called "permanent" gases. The first man to attack the problem systematically was Michael Faraday, who before the end of the first third of the century had liquefied several gases, mostly by reducing them by chemical reactions under pressure. Several of the more easily reducible gases or vapors, such as ammonia, sulphurous acid, and probably chlorine, had been previously liquefied by cold; but a quarter of a century elapsed after Faraday's researches before the true relation of the liquid and gaseous states of matter was understood, and it was found that both increase of pressure and lowering of temperature were, in general, essential to the liquefaction of a gas. It was Thomas Andrews, of Belfast, who first showed in a paper published in 1863 that there was a continuity in the liquid and gaseous states of matter; that for each substance there was a critical temperature at which it became a homogeneous fluid, neither a liquid nor a gas; that above this temperature great pressure would not liquefy, while below it the substance might exist as partly liquid and partly gas. He pointed out the fact that for the so-called permanent gases this critical temperature must be exceedingly low and if such temperature could be reached liquefaction would follow.

Subsequent progress in the liquefaction of gases came about by following this suggestion. Very low temperatures were produced by subjecting the gas to great reduction in volume by pressure, removing the heat of compression by conduction and radiation, and then by sudden expansion its temperature was greatly lowered. As early as 1877 two Frenchmen, Pictet and Cailletet, had succeeded in liquefying oxygen, hydrogen, nitrogen, and air. During the past twenty years great improvements have been made in the methods of accomplishing these transformations, so that to-day it is easy to produce considerable quantities of all of the principal gases in a liquid form, and by carrying the reduction in temperature still further portions of the liquid may be changed to the solid state. The most important work along this line has been done by Wroblewski and Olszewski of the University of Kracow, and Professor Dewar, of the Royal Institution of London. Temperatures as low as about 250° C. below the freezing point of water have been produced, the "absolute zero" being only 273° C. below that point. These experiments promise to throw much light on the nature of matter and are especially interesting as revealing its extraordinary properties at extremely low temperatures. Among the most curious and suggestive is the fact that the electrical resistance of pure metals diminishes at a rate which indicates that at the absolute zero it would vanish and these metals would become perfect conductors of electricity.

The dynamics of heat, or "thermodynamics," was an important field of research in the early part of the century, on account of its practical application to the improvement of the steam engine. The science was created by Carnot, who, in spite of the fact that his views regarding the nature of heat were erroneous, discovered some of the most interesting relations among the quantities involved and discussed their applications to the heat engines with great skill. Subsequent contributors to the theory and practice of thermodynamics were Clausius, Rankine, Lord Kelvin, and Professor Tait.

The mechanical theory of heat naturally led up to what has already been referred to as the most important generalization in physical science since the time of Newton—the doctrine of

THE CONSERVATION OF ENERGY.

This principle puts physics in its relation to energy where chemistry has long been in its relation to matter. If matter were not conservative, if it could be created or destroyed at will, chemistry would be an impossible science. Physics is put upon a solid foundation by the assumption of a like conservatism in energy; it can neither be created nor destroyed, although it may appear in many different forms which are in general mutually interconvertible.

Many men have contributed to the establishment of this great principle, but it was actually discovered and proved by the labors of three or four. Although it was practically all done before the middle of the nineteenth century, its general popular recognition did not come until a quarter of a century later. The doctrine was first distinctly formulated by Robert Mayer, a German physician, who published in 1842 a suggestive paper on "The forces of inorganic nature," which, however, attracted little or no attention. Mayer had not approached the problem from an experimental standpoint. At about the same time it was attacked most successfully from this side by a young Englishman, James Prescott Joule, son of a wealthy brewer of Manchester, England. Joule made the first really accurate determination of the mechanical equivalent of a given quantity of heat, a physical constant which Rumford had tried to measure, reaching only a rough approximation. Substantially Joule's result was that the heat energy necessary to raise the temperature of any given mass of water 1° F. is the equivalent of the mechanical energy required to lift that mass through a height of 772 feet against the force of the earth's attraction, and, conversely, if a mass of water be allowed to fall through a distance of 772 feet under the action of gravity and at the end of its motion be instantly arrested, the heat generated will suffice to raise its temperature 1° F. Of such vast importance is this numerical coefficient that it has been called the "golden number" of the nineteenth century. Since Joule's time it has been redetermined by several physicists, notably by Professor Rowland, of Baltimore, the general conclusion being that Joule's number was somewhat, but not greatly, too small.

The first clear and full exposition of the doctrine of the conservation of energy was given by Joule in a popular lecture in Manchester in 1847, but it attracted little attention until a few months later, when the author presented his theory at a meeting of the British Association for the Advancement of Science. Even among scientific men it would have passed without comment or consideration had it not been for the presence of another young Englishman, then as little known as Joule himself, who began a series of remarks, appreciative and critical, which resulted in making Joule's paper the sensation of the meeting. This was William Thomson, who had been only a year before, at the age of 22 years, appointed professor of natural philosophy at the University of Glasgow, now known as Lord Kelvin, the most versatile, brilliant, and profound student of physical science which the century has produced. From that day to the death of Joule (1889) these two men were closely associated in the demonstration and exploitation of a great principle of which they were at first almost the sole exponents among English-speaking people.

By an interesting coincidence, in the same year in which Joule announced the result of his experiments the Physical Society of Berlin listened to a paper almost identical with Joule's in character and conclusions, but prepared quite independently, by a young German physician, Herman von Helmholtz, destined to rank at the time of his death (in 1893) as one of the very first mathematicians of the age, doubtless the first physiologist of his time, and as a physicist with whom not more than one other of the nineteenth century can be compared. Helmholtz's paper was rejected by the editor of the leading scientific journal of Germany, but his work was so important that he must always share with Joule and Kelvin in the glory of this epoch-making generalization.

Even a brief sketch of the history of the doctrine of the conservation of energy would be incomplete if mention were not made of the work of Tyndall. Although by original research he contributed in no small degree to the demonstration of the theory, it is mainly through his wonderful skill in popular presentation of the principles of physical science that he becomes related to the great movement in the middle of the century. His masterful exposition of the new theory in a course of lectures at the Royal Institution, given in 1862 and published in 1863 under the title "Heat as a mode of motion," was a means of making the intelligent public acquainted with its beauty and profound significance, and the history of science affords no more admirable example of the possibilities and wisdom of popular scientific writing than this book. As for the principle of the conservation of energy itself, it is not too much to say that during the last half of the century it has been the guiding and controlling spirit of all scientific discovery, or of invention through the application of scientific principles.

LIGHT.

The revival and final establishment of the undulatory or wave theory of light is one of the glories of the nineteenth century, and the credit for it is due to Thomas Young, an Englishman, and Fresnel, a Frenchman. Newton had conceived, espoused, and, owing to the great authority of his name, almost fixed upon the learned world the corpuscular or emission theory, which assumes that all luminous bodies emit streams of minute corpuscles which are reflected, refracted, and produce vision. Many ordinary optical phenomena were explained by this hypothesis only with great difficulty, and some were quite unexplainable. The transmission of a disturbance or vibratory motion by means of waves, as in the case of sound, was a well-recognized principle, and Young and Fresnel applied it most successfully to the phenomena of light. Wave motion in a general way is only possible in a sensibly continuous medium, such as water, air, etc., and the theory that light was a vibratory disturbance transmitted by means of waves necessitated the assumption of the existence of such a medium throughout all space in which light traveled. What is known as the ethereal medium, at first a purely imaginary substance, but whose real existence is practically established, satisfies this demand, and the hypothesis that light is transmitted by waves in such a medium, originating in a vibratory disturbance at the source, has been of inestimable value to physical science.

The work of Thomas Young was done in the very first years of the nineteenth century. He was for two years professor of natural philosophy in the Royal Institution just founded by Count Rumford, and was the first to fill that chair. In 1801, in a paper presented to the Royal Society, he argued in favor of the undulatory theory, showing how the interference of waves would explain the color of thin plates. His papers were not for several years received favorably, and they were severely criticised by Lord Brougham. Augustus Fresnel followed Young, but quite independently, about ten years later, and by him the undulatory theory received elaborate experimental and mathematical treatment.

In the meantime another Frenchman had made a capital discovery in optics, which seemed at first to be quite incompatible with the wave theory. This was the discovery of what is known as polarization of light, by Malus, a French engineer, who hit upon it while investigating double refraction of crystals, for a study of which the French Institute had offered a prize in 1808. Malus found that when light fell upon a surface of glass at a certain angle a portion of the reflected light appeared to have acquired entirely new properties in regard to further reflection, and the same was true of that part of the beam which was transmitted through the glass. The light thus affected was incapable of further reflection under certain conditions and as the beam seemed to behave differently according to how it was presented to the reflecting surface the term polarization was applied to the phenomenon. It was found that the two rays into which a single beam of light was split by a doubly refracting crystal (a phenomenon which had long been known) were affected in this way, and that light was polarized by refraction as well as by reflection. Malus was a believer in the corpuscular theory of light; but it was shortly proved, first by Thomas Young, that the phenomenon of polarization was not only not opposed to the wave theory, but that that theory furnished a rational explanation of it. This explanation, in brief, assumes that ordinary light is a wave produced by a vibratory motion confined to no particular plane, the direction of vibration being at right angles to the direction of the wave and in any or in rapid succession in all azimuths. When light is polarized, the vibratory motion in the ether is restricted to one particular form, a line if plane polarized, a circle or an ellipse if circularly or elliptically polarized. This simple hypothesis has been found quite adequate, and through its application to the various phenomena of polarization, together with the application of Young's theory of the interference of waves to the production of color, the undulatory theory of light was firmly established before the middle of the century. There were many noted philosophers, however, who stood out long against it, notably Brewster, the most famous English student of optics of the early part of the century, who declared that his "chief objection to the undulatory theory was that he could not think the Creator guilty of so clumsy a contrivance as the filling of space with ether in order to produce light."

In studying the nature of light it became very important to know how fast a light wave traveled. A tolerably good measure of the velocity of light had been made long before by means of the eclipses of Jupiter's moons and by observations upon the positions of the stars as influenced by the motion of the earth in its orbit. It was found to be approximately 180,000 miles per second, a speed so great that it seemed impossible that it should ever be measured by using only terrestrial distances. This extremely difficult problem has been solved, however, in a most satisfactory manner by nineteenth century physicists. Everybody knows that in a uniform motion velocity is equal to space or distance divided by time. If, then, the time occupied in passing through a given distance can be measured, the velocity is at once known. As the velocity of light is very large, unless the distance is enormously great the time will be extremely small, and if moderate distances are to be used, the problem is to measure very small intervals of time very accurately. Light will travel 1 mile in about the one hundred and eighty-sixth thousandth part of a second, and if by using a mile as the distance the velocity of light is to be determined within 1 per cent, it is necessary to be able to detect differences of time as small as about one-twenty-millionth of a second. This has been made possible by the use of two distinct methods. Foucault, on the suggestion of Arago, used a rapidly revolving mirror, a method introduced by Wheatstone, the English electrician, who used it in finding the duration of an electric spark. The essential principle is that a mirror may be made to revolve so rapidly that it will change its position by a measurable angle while light which has been reflected from it passes to a somewhat distant fixed mirror and returns to the moving reflector. In the other method a toothed wheel is revolved so rapidly that a beam of light passing between two consecutive teeth to a distant fixed mirror is cut off on its return to the wheel by the tooth which has moved forward while the light has made its journey. This method was first used by Fizeau. In either method, if the speed of rotation is known, the time is readily found. In point of time Fizeau was the first to attack the problem, which he did about

1849. Foucault was perhaps a year later in getting results, but his method is generally considered the best. Both methods have been used by other experimenters, and very important improvements in Foucault's method were made in the United States about 1878. Michelson's method increased enormously the precision of the measurements, and it has been applied by him and by Newcomb, not only for the better determination of the velocity of light in air, but for the solution of many other related problems of first importance. Michelson's final determination of the absolute velocity of light (in the ether) is everywhere accepted as authoritative.

Another discovery in optics, entirely accomplished during the nineteenth century and of the very first importance, is generally known as spectrum analysis. This discovery has not yet ceased to excite admiration and even amazement, and especially among those who best understand it. By its use hitherto unknown substances have become known; to the physicist it is an instrument of research of the greatest power, and, perhaps more than anything else, it promises to throw light on the ultimate nature of matter; to the astronomer it has revealed the composition, physical condition, and even the motions of the most distant heavenly bodies, all of which the philosophy of a hundred years ago would have pronounced absolutely impossible.

The beginning of spectrum analysis was in 1802, when an Englishman, Dr. Wollaston, observed dark lines interrupting the solar spectrum when produced by a good prism upon which the sunlight fell after passing through a narrow slit. About ten years later Fraunhofer, of Munich, a skillful worker in glass and a keen observer, discovered in the spectrum of light from a lamp two yellow bands, now known as the sodium or "D" lines. Combining the three essential elements of the modern spectroscope—the slit, the prism, and the observing telescope—he saw in the spectrum of sunlight "an almost countless number of dark lines." He was the first to use a grating for the production of the spectrum, using at first fine wire gratings and afterwards ruling fine lines upon glass, and with these he made the first accurate measures of the length of light waves. He did not, however, comprehend the full import of the problem which he thus brought to the attention of physicists. About twenty years later Sir John Herschell studied the bright-line spectra of different substances and found that they might be used to detect the presence of minute quantities of a substance whose spectrum was known. Wheatstone studied the spectrum of the electric arc passing between metals, and in 1847 Dr. J. W. Draper published a very important paper on the spectra of solids with increasing temperature. Although quite in the dark as to the real nature of the phenomena with which they were dealing, these observers paved the way for the splendid work of the two Germans, Kirchoff and Bunsen, who, about 1860, found the key to this wonderful problem and made the science of spectrum analysis substantially what it is to-day. Its fundamental principles may be considered as few and comparatively simple.

Waves of light and radiant heat originate in ether disturbances produced by molecular vibration and have impressed upon them all of the important qualities of that vibration. Molecules of different substances differ in their modes of vibration, each producing a wave peculiar to and characteristic of itself. A useful analogy may be found in the fact that when one listens to the music of an orchestra without seeing it, it is easy to recognize the tones that come from each of the several instruments, the characteristic vibrations of each being impressed upon the waves in air which carry the sound to the ear. So delicate and so sure is this impression of vibration peculiarities that it is possible even to know the maker of a violin, for instance, by a characteristic timbre which must have its physical expression in the sound wave. The ear, more perfect than the eye, analyzes the resultant disturbance into its component parts, so that each element may be attributed to its proper source. Unaided the eye can not do this with light, but the spectroscope separates the various modes of vibration which make up the confused whole, so that varieties of molecular activity are recognizable. The speed at which a source of sound is approaching or receding from the ear can be ascertained by noting the rise or fall in pitch due to the crowding together or stretching out of the sound waves, and in the same way the motion of a luminous body is known from the increase or decrease of the refrangibility of the elements of its spectrum.

Indeed, had nineteenth century science accomplished nothing else than the discovery of spectrum analysis, it would have marked the beginning of a new epoch. By this device man is put in communication with every considerable body in the universe, including even the invisible. The "goings on" of Sirius and Algol, of Orion and the Pleiades, are reported to him across enormous stretches of millions of millions of miles of space, empty save of the ethereal medium itself, by this most wonderful "wireless telegraphy." And it is by the vibratory motion of the invisibly small that all of this is revealed; the infinitely little has enabled us to conquer the inconceivably big.

Many important contributions to the theory and practice of spectrum analysis have been made since the time of Kirchoff and Bunsen, only two or three of which can be referred to here. Instrumental methods by which spectra are produced and examined have been greatly perfected, and this is especially true of what is known as the "diffraction grating," first used by Fraunhofer. A quarter of a century ago Rutherfurd, of New York, constructed a ruling engine, by means of which gratings on glass and spectrum metal were ruled with a precision greatly exceeding what had before been possible. A few years later Rowland, of Baltimore, made a notable advance in the construction of a screw far more perfect than any before made, producing gratings of a fineness and regularity of spacing far ahead of any others, and especially by a capital discovery of the concave grating, by means of which the most beautiful results have been obtained. Very recently, Michelson, of Chicago, has invented the echelon spectroscope, which, although greatly restricted in range, exceeds all others in power of analysis of spectral lines. In his hands this instrument has been most effective in the study of the influence of a strong magnetic field upon the character of the spectrum from light produced therein, a most interesting phenomenon, first observed by Zeeman, which promises to reveal much concerning the relation of molecular activity to light and to magnetic force.

The development of spectrum analysis was necessarily accompanied by a recognition of the identity of radiant heat and light. The study of radiant heat, which was carried on during the earlier years of the century by Leslie, and later by Melloni and Tyndall, by what might be called thermal methods, has been industriously pursued during the last two decades by processes similar to those adopted for visual radiation. The most notable contribution to this work is the invention of the bolometer by Langley, who, at Allegheny and later at Washington, has made exhaustive studies of solar radiation in invisible regions of the spectrum, especially among the waves of greater length than those of red light, where he has found absorption lines and bands similar in character to those observed in the visible spectrum. He has also studied the absorption of the earth's atmosphere, the relation of energy to visual effect, and many other interesting problems, the solution of which was made possible by the use of the bolometer.

Mention must also be made of the invention by Michelson of an interference comparator, by means of which linear measurements by optical methods can be accomplished with a degree of accuracy hitherto unheard of. With this instrument Michelson has determined the length of the international prototype meter in terms of the wave length of the light of a particular spectral line, thus furnishing for the first time a satisfactory natural unit of length.

By far the most important contribution to the theory of light made during the last half of the century is that of Maxwell, who, in 1873, announced the proposition that electro-magnetic phenomena and light phenomena have their origin in the same medium and that they are identical in nature. This far-reaching conclusion has been generally accepted and forms the basis of much of the most important work in physical research in process of elaboration as the century closes. To some of this reference will presently be made.

ELECTRICITY AND MAGNETISM.

In no other department of physical science have such remarkable developments occurred during the past century as in electricity and magnetism, for in no other department have the practical applications of scientific discovery been so numerous and so far-reaching in their effect upon social conditions. In a brief review of the contributions of the nineteenth century to the evolution of the telegraph, telephone, trolley car, electric lighting, and other means of utilizing electricity, it will be possible to consider only a very few of the fundamental discoveries upon which the enormous and rather complex superstructure of to-day rests. Happily these are few in number, and their presentation is all the more important because of the fact that in the popular mind they do not receive that significance to which they are entitled, if, indeed, they are remembered at all.

The first great step in advance of the electricity of Franklin and his contemporaries (and his predecessors for two thousand years) was taken very near the end of the eighteenth century, but it must be regarded as the beginning of nineteenth century electricity. Two Italian philosophers, Galvani and Volta, contributed to the invention of what is known as the galvanic or voltaic battery, the output of which was not at first distinctly recognized as the electricity of the older schools. By this beautiful discovery electricity was for the first time enslaved to man, who was now able to generate and control it at such times and in such quantities as he desired. Although the voltaic battery is now nearly obsolete as a source of electricity, its invention must always be regarded as one of the three epoch-making events in the history of the science during the past one hundred and twenty years. For three-quarters of a century it was practically the only source of electricity, and during this time and by its use nearly all of the most important discoveries were made. Even in the first decade of the century many brilliant results were reached. Among the most notable were the researches of Sir Humphry Davy, who, by the use of the most powerful battery then constructed, resolved the hitherto unyielding alkalies, discovering sodium and potassium, and at the same time exhibited in his lectures in the Royal Institution in London the first electric arc light, the ancestor of the millions that now turn night into day.

The cost of generating electricity by means of a voltaic battery is relatively very great, and this fact stood in the way of the early development of its applications, although their feasibility was perfectly well understood. Without any other important invention or discovery than that of the voltaic battery much would have been possible, including both electric lighting and the electric telegraph. Indeed, electric telegraphy had long been a possibility, even before the time of Galvani and Volta, but its actual construction and use were almost necessarily postponed until a second capital discovery came to remove most of the difficulties.

This was the discovery of a relation between electricity and magnetism, the existence of which had long been suspected and earnestly sought. A Danish professor, Hans Christian Oersted, was fortunate in hitting upon an experiment which demonstrated this relation and opened up an entirely new field of investigation. What Oersted found was that when a conductor, as a copper wire, carrying an electric current was brought near a freely suspended magnet, like a compass needle, the latter would take up a definite position with reference to the current. Thus an electric current moved a magnet, and acted like a magnet in producing a "magnetic field." The subject was quickly taken up by almost every physicist in Europe and America. Arago found that iron filings would cling to a wire through which a current was passing, and he was able to magnetize steel needles by means of the current. Ampère, another French physicist, studied Oersted's wonderful discovery both experimentally and mathematically and in an incredibly short time so developed it as to deserve the title of creator of the science of electro-dynamics.

The first to make what is known as an electro-magnet was an Englishman named Sturgeon, who used a bar of soft iron bent in a horseshoe form (as had long been common in making permanent steel magnets), and after varnishing the iron for insulation wrapped a single coil of copper wire about it through which the current from a battery was passed. There were thus two ways of producing visible motion by means of an electric current, that of Oersted's simple experiment, in which a suspended magnetic needle was deflected by a current, and that made possible by the production, at will, of an electro-magnet. The application of both of these ideas to the construction of an electric telegraph was quickly attempted, and two different systems of telegraphy grew out of them. One, depending on Oersted's experiment, was developed in England first and afterwards in Europe; the other, that involving the use of signals produced by an electric magnet, was developed in America and was generally known as the American method. It has long ago superseded the first method in actual practice. Its possibility depended on perfecting the electro-magnet and especially on an understanding of the principles on which that perfecting depended. For the complete and satisfactory solution of this problem we are indebted to the most famous student of electricity America has produced during the century, Joseph Henry.

In 1829, while a teacher in the academy at Albany, N. Y., Henry exhibited an electro-magnet of enormously greater power than any before made, involving all of the essential features of the magnet of to-day. The wire was insulated by silk wrapping, and many coils were placed upon the iron core, the intensity of magnetization being thus multiplied. Henry studied also the best form and arrangement of the battery under varying conditions of the conductor. An electro-magnetic telegraph had been declared impossible in 1825 by Barlow, an Englishman, who pointed out the apparently fatal fact that the resistance offered to the current was proportional to the length of the conducting wire, and that the strength of the current would be thus so much reduced, for even short distances, as to become too feeble to be detected. Henry showed that what is known as an "intensity battery" would overcome this difficulty, discovering experimentally and independently the beautifully simple law showing the relation of current to electromotive force which Ohm had announced in 1827. He also invented the principle of the relay, by which the action of a very feeble current controls the operation of a more powerful local system. It will thus be seen that the essential features of the so-called American system of telegraphy are to be credited to Henry, who had a working line in his laboratory as early as 1832.

Morse made use of the scientific discoveries and inventions of Henry, and by his indefatigable labors and persistent faith the commercial value of the enterprise was really established. In the meantime considerable progress was made in Europe. Baron Schilling, a Russian councilor of state, devised and exhibited a needle telegraph. The two illustrious German physicists, Gauss and Weber, established a successfully working line 2 or 3 miles long in 1833, and this system was commercially developed by Steinheil in 1837. In England, Sir Charles Wheatstone made many important contributions, although using the needle system, which was afterwards abandoned. Before the middle of the century the commercial success of the electro-magnetic telegraph was assured, and in the matter of the transmission of messages distance was practically annihilated.

Oersted, Arago, Ampère, Sturgeon, and Henry had made it possible to convert electricity into mechanical energy. Motors of various types had been invented, and the possibility of using the new source of power for running machinery, cars, boats, etc., was fully recognized. Several attempts had been made to do these things, but the great cost of producing the current by means of a battery stood in the way of success. Another epoch-making discovery was necessary—namely, a method of reversing the process and converting mechanical energy into electricity. This was supplied by the genius of Michael Faraday, who had succeeded Davy in the Royal Institution at London. In 1831 Faraday discovered induction, the key to the modern development of electricity. He showed that while Oersted had proved that a current of electricity would generate a magnetic field and set a magnet in motion, this process was reversible. A magnet set in motion in a magnetic field by a steam engine or any other source of power would produce in a conductor properly arranged a current of electricity, and thus the dynamo came into existence. In this brilliant investigation he was almost anticipated by Henry, who was working at Albany along the same lines, but under much less favorable conditions. Indeed, in several of the most important points the American actually did anticipate the Englishman.

Nearly half a century elapsed before this most important discovery was sufficiently developed to become commercially valuable, and it is impossible in this place to trace the steps by which during the last quarter of a century the production and utilization of electricity as existing to-day was accomplished, as a result of which the century closes, as one might say, in a blaze of light; and it is unnecessary, because most people have witnessed the spread of the fire which Faraday and Henry kindled.

Faraday's discovery of induction furnished the basis of that marvelous improvement upon the telegraph by which actual speech is transmitted over hundreds and even thousands of miles. In connection with the invention of the telephone the names of Philip Reiss, Graham Bell, Elisha Gray, and Dolbear will always be mentioned, each of whom, doubtless independently, hit upon a way of accomplishing the result with more or less success. To Bell, however, belongs the honor of having first practically solved the problem, and of devising a system which, with numerous modifications and improvements, has come into extensive use in all parts of the world. No other application of electricity has come into such universal use, and none has contributed more to the comfort of life.

While it is doubtless true that since Faraday's time no discovery comparable with his in real importance has been made, the past twenty-five years have not lacked in results of scientific research, some of which may, in the not distant future, eclipse even that in the value of their practical applications. Among these must be ranked Clerk Maxwell's theory of electric waves and its beautiful verification in 1888 by the young German physicist, Hertz. This brilliant student of electricity succeeded in actually producing, detecting, and controlling these waves, and out of this discovery has come the "wireless telegraphy" which has been so rapidly developed within the last few years. Many other discoveries in electricity of great scientific interest and practical promise have been recorded in the closing years of the century, but the necessary limits of this article forbid their consideration.

No account of the progress of physical science during the nineteenth century would be even approximately complete without mention of other investigations of profound significance. For instance, the study of the phenomena of sound has yielded results of great scientific and some practical value. The application of the theory of interference by Thomas Young; the publication of Helmholtz's great work, the Tonempfindungen, in which his theory of harmony was first fully presented; the publication of Lord Rayleigh's treatise; the invention and construction by König of acoustic apparatus, the best example yet furnished of scientific handicraft. All of these mark important advances, not only in acoustics, but in general physics as well. The phonautograph of Scott and König, by which a graphic record of the vibrations of the vocal cords was made possible, was ingeniously converted by Edison into a speech recording and reproducing machine, the phonograph, by which the most marvelous results are accomplished in the simplest possible manner.

The century is also to be credited with the discovery and development of the art of photography, which, although not of the first importance, has contributed much to the pleasure of life, and as an aid to scientific investigation has become quite indispensable.

The wonderfully beautiful experiments of Sir William Crookes, on the passage of an electric discharge through a high vacuum, and other phenomena connected with what has been called "radiant matter," begun about a quarter of a century ago and continued by him and others up to the present time, laid the foundation for the brilliant work of Röntgen in the discovery and study of the so-called "X" rays, the real nature of which is not yet understood. Their further investigation by J. J. Thomson, Becquerel, and others seem to have revealed new forms and phases of radiation, a fuller knowledge of which is likely to throw much light on obscure problems relating to the nature of matter.

Concerning the nature of matter, the ablest physicists of the century have thought and written much, and doubtless our present knowledge of the subject is much more nearly the truth than that of a hundred years ago. The molecular theory of gases has met with such complete experimental verification and is so in accord with all observed phenomena that it must be accepted as essentially correct. As to the ultimate nature of what is called matter, as distinguished from the ethereal medium, what is known as the "vortex theory of atoms" has received the most consideration. This theory was developed by Lord Kelvin out of Helmholtz's mathematical demonstration of the indestructibility of a vortex ring when once formed in a medium possessing the properties which are generally attributed to the ether.

Perhaps the most remarkable as well as the most promising fact relating to physical science at the close of the nineteenth century is the great and rapidly increasing number of well-organized and splendidly equipped laboratories in which original research is systematically planned and carried out. When one reflects that for the most part during the century just ending the advance of science was more or less of the nature of a guerrilla warfare against ignorance, it seems safe to predict for that just beginning victories more glorious than any yet won.

ELECTRICITY DURING THE NINETEENTH CENTURY.[1]

By Prof. Elihu Thomson.

The great importance which electricity has attained in many departments of human activity is so constantly evident that we have difficulty in realizing how short is the time which has been occupied in its development. The latter half of the nineteenth century must ever remain memorable, not only for the great advances in nearly all the useful arts, but for the peculiarly rapid electric progress, and the profound effect which it has had upon the lives and business of the people. In the preceding century we find no evidences of the application of electricity to any useful purpose. Few of the more important principles of the science were then known. Franklin's invention of the lightning rod was not intended to utilize electric force, but to guard life and property from the perils of the thunderstorm. The numerous instructive experiments in frictional electricity, the first known form of electric manifestation except lightning, made clear certain principles, such as conduction and insulation, and served to distinguish the two opposite electric conditions known as positive and negative. Franklin's kite experiment confirmed the long-suspected identity of lightning and electric sparks. It was not, however, until the discovery by Alexander Volta in 1799 of his pile, or battery, that electricity could take its place as an agent of practical value. Volta, when he made this great discovery, was following the work of Galvani, begun in 1786. But Galvani in his experiments mistook the effect for the cause and so missed making the unique demonstration that two different metals immersed in a solution could set up an electric current. Volta, a professor in the University of Pavia and a foreign member of the Royal Society of England, communicated his discovery to the president of the society in March, 1800, and brought to the notice of the world the first means for obtaining a steady flow of electricity. Before this event electric energy had been known to the experimenter in pretty effects of attraction and repulsion of light objects, in fitful flashes of insignificant power, or as it appeared in nature, in the fearful bursts of energy during a thunderstorm, uncontrolled and erratic. The

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analogous and closely related phenomena of magnetism had already found an important application in the navigator's compass.

The simplest facts of electro-magnetism, upon which much of the later electrical developments depend, remained entirely unknown until near the close of the first quarter of the nineteenth century. Magnetism itself, as exemplified in loadstone or in magnetized iron or steel, had long before been consistently studied by Dr. Gilbert, of Colchester, England, and in 1690 his great work, De Magnete, was published. It is a first example, and an excellent one, too, of the application of the inductive method, so fruitful in after years. The restraints which a superstitious age had imposed upon nature study were gradually removed, and at the beginning of the century just past occasional decided encouragement began to be given to physical research. It was this condition which put into the hands of Humphry Davy, of the Royal Institution in London, at the opening of the century, a voltaic battery of some 250 pairs of plates. With this a remarkably fruitful era of electric discovery began. In 1802 Davy first showed the electric arc or "arch" on a small scale between pieces of carbon. He also laid the foundation for future electro-chemical work by decomposing by the battery current potash and soda, and thus isolating the alkali metals potassium and sodium for the first time. This was in 1807, and the result was not only greatly to advance the youthful science of chemistry, but to attract the attention of the world to a new power in the hands of the scientific worker, the electric current. A fund was soon subscribed by "a few zealous cultivators and patrons of science" interested in the discovery of Davy, and he had at his service in 1801 no less than 2,000 cells of voltaic battery. With the intense currents obtained from it he again demonstrated the wonderful and brilliant phenomenon of the electric arc by closing the circuit of the battery through terminals of hard-wood charcoal and then separating them for a short distance. A magnificent arch of flame was maintained between the separated ends, and the light from the charcoal pieces was of dazzling splendor. Thus was born into the world the electric arc light, of which there are now hundreds of thousands burning nightly in our country alone.

Davy probably never imagined that his brilliant experiment would soon play so important a part in the lighting of the world. He may never have regarded it as of any practical value. In fact, many years elapsed before any further attempt was made to utilize the light of the electric arc. The reason for this is not difficult to discover. The batteries in existence were crude and gave only their full power for a very short time after the circuit was closed. They were subject to the very serious defect of rapid polarization, whereby the activity was at once reduced. A long period elapsed before this defect was removed. Davy, in his experiments, had also noted the very intense heat of the electric arc and found that but few substances escaped fusion or volatilization when placed in the heated stream between the carbon electrodes. Here again he was pioneer in every important and quite recent electric work, employing the electric furnace, which has already given rise to several new and valuable industries.

The conduction of electricity along wires naturally led to efforts to employ it in signaling. As early as 1774 attempts were made by Le Sage of Geneva to apply frictional electricity to telegraphy. His work was followed before the close of the century by other similar proposals. Volta's discovery soon gave a renewed impetus to these efforts. It was easy enough to stop and start a current in a line of wire connecting two points, but something more than that was requisite. A good receiver, or means for recognizing the presence or absence of current in the wire or circuit, did not exist. The art had to wait for the discovery of the effects of electric currents upon magnets and the production of magnetism by such currents. Curiously, even in 1802, the fact that a wire conveying a current would deflect a compass needle was observed by Romagnosi, of Trente, but it was afterwards forgotten, and not until 1819 was any real advance made.

It was then that Oersted, of Copenhagen, showed that a magnet tends to set itself at right angles to the wire conveying a current, and that the direction of turning depends on the direction of the current. The study of the magnetic effects of electric currents by Arago and Ampère, and the production of the electro-magnet by Sturgeon, together with the very valuable work of Henry and others, made possible the completion of the electric telegraph. This was done by Morse and Vail in America, and almost simultaneously by workers abroad; but before Morse had entered the field Prof. Joseph Henry had exemplified by experiments the working of electric signaling by electro-magnets over a short line. It was Henry, in fact, who first made a practically useful electro-magnet of soft iron. The history of the electric telegraph teaches us that to no single individual is the invention due. The Morse system had been demonstrated in 1837, but not until 1844 was the first telegraph line built. It connected Baltimore and Washington, and the funds for defraying its cost were obtained from Congress only after a severe struggle. This can be easily understood, for electricity had not up to that time ever been shown to have any practical usefulness. The success of the Morse telegraph was soon followed by the establishment of telegraph lines as a means of communication between all the large cities and populous districts. Scarcely ten years elapsed before the possibility of a trans-Atlantic telegraph was mooted. The cable laid in 1858 was a failure. A few words passed and then the cable broke down completely. This was found to be due to defects in construction. A renewed effort to lay a cable was made in 1866, but disappointment again followed: the cable broke in mid ocean and the work again ceased. The great task was successfully accomplished in the following year, and the pluck and pertinacity of those who were staking their capital, if not their reputation for business sagacity, were amply rewarded. Even the lost cable of 1866 was found, spliced to a new cable, and completed soon after as a second working line. The delicate instruments for the working of these long cables were due to the genius of Sir William Thomson, now Lord Kelvin, whose other instruments for electrical measurement have for years been a great factor in securing precision both in scientific and practical testing. The number of cables joining the Eastern and Western hemispheres has been increased from time to time, and the opening of a new cable is now an ordinary occurrence calling for little or no especial note.

The introduction of the electric telegraph was followed by the invention of various signaling systems, the most important being the fire-alarm telegraph as suggested by Channing and worked out by Farmer. We now, also, have automatic clock systems, in which a master clock controls or gives movement to the hands of distant clock dials by electric currents sent out over the connecting or circuit wires. Automatic electric signals are made when fire breaks out in a building, and alarms are similarly rung when a burglar breaks in. Not only do we have telegraphs which print words and characters—as in the stock "ticker"—but in the form known as the teleautograph, invented by Dr. Elisha Gray, the sender writes his message, which writing is at the same time being reproduced at the receiving end of the line. Even pictures or drawings are "wired" by special instruments. The desirability of making one wire connecting two points do a large amount of work, and thus avoiding the addition of new lines, has led to two remarkable developments of telegraphy. In the duplex, quadruplex, and multiplex systems several messages may at the same time be traversing a single wire line without interference one with the other. In the rapid automatic systems the working capacity of the line is increased by special automatic transmitting machines and rapid recorders, and the electric impulses in the line itself follow each other with great speed.

Improvement in this field has by no means ceased, and new systems for rapid transmission are yet being worked out. The object is to enlarge the carrying capacity of existing lines connecting large centers of population. The names of Wheatstone, Stearns, Edison, and Delaney are prominent in connection with this work. For use in telegraphy the originally crude forms of voltaic battery—such as Davy used—were replaced by the more perfect types—such as the constant battery of Daniell, the nitric-acid battery of Grove, dating from 1836, and the carbon battery of Bunsen, first brought out in 1842. Such was the power of the Grove and Bunsen batteries that attention was again called to the electric arc and to the possibility of its use for electric illumination. Accordingly we find that suggestions were soon made for electric-arc lamps to be operated by these more powerful and constant sources of electric current. The first example of a working type of an arc lamp was that brought to notice by W. E. Staite, in 1847, and his description of the lamp and the conditions under which it could be worked is a remarkably exact and full statement, considering the time of its appearance. Staite even anticipated the most recent phase of development in arc lighting, namely, the inclosure of the light in a partially air-tight globe to prevent too rapid waste of the carbons by combustion in the air. In a public address at Newcastle-on-Tyne, in 1847, he advocated the use of the arc so inclosed in mines, as obviating the danger of fire. But it was a long time before the electric arc acquired any importance as a practical illuminant. There was, indeed, no hope of its success so long as the current had to be obtained from batteries consuming chemicals and zinc. The expense was too great and the batteries soon became exhausted. In spite of this fact, occasional exhibitions of arc lighting were made, notably in 1856 by Lacassagne and Thiers in the streets of Paris.

For this service they had invented an arc lamp involving what is known as the differential principle, afterwards applied so extensively to arc lamps. The length of the arc or the distance between the carbons of the lamp was controlled with great nicety, and the light thus rendered very steady. Even as late as 1875 batteries were occasionally used to work single electric arc lamps for public exhibitions, or for demonstration purposes in the scientific departments of schools. The discovery of the means of efficiently generating electricity from mechanical power constitutes, however, the keynote of all the wonderful electrical work of the closing years of the nineteenth century. It made electrical energy available at low cost. Michael Faraday, a most worthy successor of Davy at the Royal Institution, in studying the relations between electric currents and magnets, made the exceedingly important observation that a wire, if moved in the field of a magnet, would yield a current of electricity. Simple as the discovery was, its effect has been stupendous. Following his science for its own sake, he unwittingly opened up possibilities of the greatest practical moment. The fundamental principle of the future dynamo-electric machine was discovered by him. This was in 1831. Faraday's investigations were so complete and his deductions so masterly that little was left to be done by others. Electro-magnetism was supplemented by magneto-electricity. Both the electric motor and the dynamo generator were now potentially present with us. Faraday contented himself with pointing the way, leaving the technical engineer to follow. In one of Faraday's experiments a copper disk, mounted on an axis passing through its center, was revolved between the poles of a large steel magnet. A wire touched the periphery of the disk at a selected position with respect to the magnet and another was in connection with the axis. These wires were united through a galvanometer or instrument for detecting electric current. A current was noted as present in the circuit so long as the disk was turned. Here, then, was the embryo dynamo. The century closes with single dynamo machines of over 5,000 horsepower capacity and with single power stations in which the total electric generation by such machines is 75,000 to 100,000 horsepower. So perfect is the modern dynamo that out of 1,000 horsepower expended in driving it 950 or more may be delivered to the electric line as electric energy. The electric motor, now so common, is a machine like the dynamo, in which the principle of action is simply reversed; electric energy delivered from the lines becomes again mechanical motion or power.

Soon after Faraday's discoveries in magneto-electricity attempts were made to construct generators of electricity from power; but the machines were small, crude, and imperfect, and the results necessarily meager.

Pixii, in Paris, one year after Faraday's discovery was announced, made a machine which embodied in its construction a simple commutator for giving the currents a single direction of flow. This is the prototype of the commutators now found on what are called continuous-current dynamos. After Pixii followed Saxton, Clarke, Wheatstone and Cooke, Stohrer, and others, but not until 1854 was any very notable improvement made or suggested. In that year Soren Hjorth, of Copenhagen, described in a patent specification the principle of causing the electric currents generated to traverse coils of wire so disposed as to reenforce the magnetic field of the machine itself. A year subsequently the same idea was again more clearly set out by Hjorth. This is the principle of the modern self-exciting dynamo, the field magnets of which, very weak at the start, are built up or strengthened by the currents from the armature or revolving part of the machine in which power is consumed to produce electricity.

In 1856 Dr. Werner Siemens, of Berlin, well known as a great pioneer in the electric arts, brought out the Siemens armature, an innovation more valuable than any other made up to that time. This was subsequently used in the powerful machines of Wilde and Ladd. It still survives in magneto call-bell apparatus for such work as telephone signaling, in exploders for mines and blasting, and in the simpler types of electroplating dynamos.

The decade between 1860 and 1870 opened a new era in the construction and working of dynamo machines and motors. It is notable for two advances of very great value and importance. Dr. Paccinotti, of Florence, in 1860, described a machine by which true continuous currents resembling battery currents could be obtained. Up to that time machines gave either rapidly alternating or fluctuating currents, not steady currents in one direction. The Paccinotti construction, in modified forms, is now almost universally employed in dynamo machines, and even where the form is now quite different the Paccinotti type has been at least the forerunner and has undergone modifications to suit special ends in view. Briefly, Paccinotti made his armature of a ring of iron with iron projections, between which the coils of insulated wire are wound. Although full descriptions of Paccinotti's ring armature and commutator were given out in 1864, his work attracted but little attention until Gramme, in Paris, about 1870, brought out the relatively perfect Gramme machine. In the meantime the other great development of the decade took place.

Although Hjorth had, as stated before, put forward the idea that a dynamo generator might itself furnish currents for magnetizing its own magnets, this valuable suggestion was not apparently worked out until 1866, when a machine was constructed for Sir Charles Wheatstone. This appears to have been the first self-exciting machine in existence. Wheatstone read a paper before the Royal Society in February, 1867, "On the augmentation of the power of a magnet by the reaction thereon of currents induced by the magnet itself." This action later became known as the reaction principle in dynamo machines.

As often happens, the idea occurred to other workers in science almost simultaneously, and Dr. Werner Siemens also read a paper in Berlin about a month earlier than that of Wheatstone, clearly describing the reaction principle. Furthermore, a patent specification had been filed in the British patent office by S. A. Varley, December 24, 1866, clearly showing the same principle of action, and he was, therefore, the first to put the matter on record. The time was ripe for the appearance of machines closely resembling the types now in such extended use. Gramme, in 1870, adopting a modified form of the Paccinotti ring and commutator, and employing the reaction principle, first succeeded in producing a highly efficient, compact, and durable continuous-current dynamo. The Gramme machine was immediately recognized as a great technical triumph. It was in a sense the culmination of many years of development, beginning with the early attempts immediately following Faraday's discovery already referred to. Gramme constructed his revolving armature of a soft iron wire ring, upon which ring a series of small coils of insulated wire were wound in successive radial planes. These coils were all connected into a continuous wire, and from the junctions of the coils one with another connections were taken to a range of copper bars insulated from each other, constituting the commutator. In 1872 Von Hefner Alteneck, in Berlin, modified the ring winding of Gramme, and produced the "drum winding," which avoided the necessity for threading wire through the center of the iron ring, as in the Gramme construction. The several coils of the drum were still connected, as in Gramme's machine, to the successive strips of the commutator.

In modern dynamos and motors the armature, usually constructed of sheet-iron punchings, is a ring with projections, as in Paccinotti's machine, and the coils of wire are in most cases wound separately and then placed in the spaces between the projections, constituting in fact a form of drum winding. In the early seventies a few Gramme ring and Siemens drum machines had been applied to the running of arc lights, one machine for each light. There were also some Gramme machines in use for electroplating.

In all dynamos in practical use the currents which are generated are alternating currents, as they are called. Such currents are characterized by rapid changes of direction or reversals. These occur many times per second, and when such currents are to be made into continuous currents flowing in one direction, the machine is provided with a commutator for connecting the coils to the circuit, so that the current will always flow in it in the same direction. Great numbers of dynamos, however, are used without commutators for changing the direction of their currents. In such machines the circuit receives, instead of continuous currents, waves of current or alternating currents. As with sound, the waves have a pitch—i. e., they follow each other at a certain number of times per second. In usual practice there will be from 25 waves, which would be a low period, up to 150 or more per second, but machines can be constructed to produce alternating currents of many thousand waves or cycles (as they are termed) per second for special uses. When an alternating current flows from a line, there are times when the current is changing from one direction to the other and when there is actually no current, and these are called the zeros or dead points of the current. Much of the machinery developed in later years has been of the alternating-current type, generators, motors, etc., utilizing these rapidly reversing currents.

At the Centennial Exhibition, held at Philadelphia in 1876, but two exhibits of electric-lighting apparatus were to be found. Of these one was the Gramme and the other the Wallace-Farmer exhibit. The Wallace-Farmer dynamo machine is a type now obsolete. It was not a good design, but the Wallace exhibit contained other examples reflecting great credit upon this American pioneer in dynamo work. Some of these machines were very similar in construction to later forms which went into very extensive use. The large searchlights occasionally used in night illumination during the exhibition were operated by the current from Wallace-Farmer machines. The Gramme exhibit was a remarkable exhibit for its time. Though not extensive, it was most instructive. There were found in it a dynamo running an arc lamp, a large machine for electrolytic work, such as electroplating and electrotyping, and, most novel and interesting of all, one Gramme machine driven by power was connected to another by a pair of wires and the second ran as a motor. This in turn drove a centrifugal pump and raised water which flowed in a small fall or cataract. A year or two previously the Gramme machine had been accidentally found to be as excellent an electric motor as it was a generating dynamo. The crude motors of Jacobi, Froment, Davenport, Page, Vergnes, Gaume, and many others, were thus rendered obsolete at a stroke. The first public demonstration of the working of one Gramme machine by another was made by Fontaine at the Vienna Exhibition of 1873.

Here, then, was a foreshadowing of the great electric power transmission plants of to-day; the suggestion of the electric station furnishing power as well as light, and to a less degree the promise of future railways using electric power. Replace the centrifugal pump of this modest exhibit by a turbine wheel, reverse the flow of water so as to cause it to drive the electric motor so that the machine becomes a dynamo, and in like manner make of the dynamo a motor, and we exemplify in a simple way recent great enterprises using water power for the generation of the current to be transmitted over lines to distant electric motors or lights.

The Centennial Exhibition also marks the beginning, the very birth, it may be said, of an electric invention destined to become, before the close of the century, a most potent factor in human affairs. The speaking telephone of Alexander Graham Bell was there exhibited for the first time to the savants, among whom was the distinguished electrician and scientist, Sir William Thomson. For the first time in the history of the world a structure of copper wire and iron spoke to a listening ear. Nay, more, it both listened to the voice of the speaker and repeated the voice at a far-distant point. The instruments, were, moreover, the acme of simplicity. Within a year many a boy had constructed a pair of telephones at an expenditure for material of only a few pennies. In its first form the transmitting telephone was the counterpart of the receiver, and they were reversible in function. The transmitter was in reality a minute dynamo driven by the aërial voice waves; the receiver, a vibratory motor, worked by the vibratory currents from the transmitter and reproducing the aërial motions. This arrangement, most beautiful in theory, was only suited for use on short lines, and was soon afterwards replaced by various forms of carbon microphone transmitter, to the production of which many inventors had turned their attention, notably Edison, Hughes, Blake, and Hunnings. In modern transmitters the voice wave does not furnish the power to generate the telephone current, but only controls the flow of an already existing current from a battery. In this way the effects obtainable may be made sufficiently powerful for transmission to listeners 1,500 miles away.

There is no need to dwell here upon the enormous saving of time secured by the telephone and the profound effect its introduction has had upon business and social life. The situation is too palpable. Nevertheless, few users of this wonderful invention realize how much thought and skill have been employed in working out the details of exchange switchboards, of signaling devices, of underground cables and overhead wires, and of the speaking instruments themselves. Few of those who talk between Boston and Chicago know that in doing so they have for the exclusive use of their voices a total of over 1,000,000 pounds of copper wire in the single line. There probably exist now in the United States alone between 75,000 and 100,000 miles of hard drawn copper wire for long-distance telephone service, and over 150,000 miles of wire in underground conduits. There are upward of 750,000 telephones in the United States, and including both overhead and underground lines, a total of more than 500,000 miles of wire. Approximately, 1,000,000,000 conversations are annually conveyed.

The possibility of suboceanic telephoning is frequently discussed, but the problem thus far is not solved. It involves grave difficulties and we may hope that its solution is to be one of the advances which will mark the coming century's progress. The advent of the telephone in 1876 seemed to stimulate invention in the electric field to a remarkable degree. Its immediate commercial success probably acted also to inspire confidence in other proposed electric enterprises. Greater attention than ever before began to be given to the problem of electric lighting. An electric arc-lamp, probably the only one in regular use, had been installed at Dungeness light-house in 1862, after a long set of trials and tests. It was fed by a Holmes magneto-electric machine of the old type, very large and cumbrous for the work. Numerous changes and improvements had before 1878 been made in arc lamps by Serrin, Duboseq, and many others, but the display of electric light during the Paris Exposition of 1878 was the first memorable use of the electric light on a large scale. The splendid illumination of the Avenue de l'Opéra was a grand object lesson. The source of light was the "electric candle" of Paul Jablochkoff, a Russian engineer. It was a strikingly original and simple arc lamp. Instead of placing the two carbons point to point, as had been done in nearly all previous lamps, he placed them side by side with a strip of baked kaolin between them. The candle so formed was supported in a suitable holder whereby at the lower end the two parallel carbons were connected with the circuit terminals. By a suitable device the arc was started at the top and burned down. The electric candle seemed to solve the problem of allowing complicated mechanism for feeding the carbons to be discarded; but it survived only a short time. Owing to unforeseen difficulties it was gradually abandoned after having served a great purpose in directing the attention of the world to the possibilities of the electric arc in lighting.

Inventors in America were not idle. By the close of 1878 Brush of Cleveland had brought out his series system of arc lights, including special dynamos, lamps, etc., and by the middle of 1879 had in operation machines, each capable of maintaining sixteen arc lamps on one wire. This was indeed a great achievement for that time. Weston, of Newark, had also in operation circuits of arc lamps, and the Thomson-Houston system had just started in commercial work with eight arc lamps in series from a single dynamo. Maxim and Fuller in New York were working arc lamps from their machines, and capital was being rapidly invested in new enterprises for electric lighting. Some of the great electric manufacturing concerns of to-day had their beginning at that time. Central lighting stations began to be established in cities, and the use of arc lights in street illumination and in stores grew rapidly. More perfect forms of light arc lamps were invented, better generating dynamos and regulating apparatus brought out. Factories for arc-light carbon making were built. The first special electrical exhibition was held in Paris in 1881. In the early eighties also the business of arc lighting had become firmly established and soon the bulk of the work was done under two of the leading systems. These were afterwards brought together under one control, thus securing in the apparatus manufactured a combination of the good features of both. Until about 1892 nearly all the arc lamps in use were worked under the series system, in which the lights were connected one after another on a circuit and traversed by the same current. This current has a standard value or is a constant current. Sometimes as many as a hundred lamps were on one wire. As the mains for the supply of incandescent lamps at constant pressure or potential were extended attention was more strongly turned to the possibility of working arc lights therefrom.

Within a few years of the close of the century this placing of arc lamps in branches from the same mains which supply incandescent lamps became common, and the inclosure of the arc in a partially air-tight globe, a procedure advocated by Staite in 1847, was revived by Howard, Marks, and others for saving carbons and attention to the lamp. The inclosed arc lamp was also found to be especially adapted to use in branches of the incandescent lamp circuits, which had in cities become greatly extended. The increasing employment of alternating currents in the distribution of electric energy has led also to the use of alternating current arc lamps, and special current-regulating apparatus is now being applied on a large scale to extended circuits of these lamps. It can be seen from these facts that the art is still rapidly progressing and the field ever widening. A little over twenty years ago practically no arc lamps were used. Now, at the close of the century, they are numbered by hundreds of thousands. The annual consumption of carbons in this country has reached 200,000,000.

Almost simultaneously with the beginning of the commercial work of arc lighting, Edison, in a successful effort to provide a small electric lamp for general distribution in place of gas, brought to public notice his carbon filament incandescent lamp.

A considerable amount of progress had previously been made by various workers in attempting to reduce the volume of light in each lamp and increase the number of lights for a given power expended. Forms of incandescent arc lamps or semiincandescent lamps were tried on a considerable scale abroad, but none have survived. So, also, many attempts to produce a lamp giving light by pure incandescence of solid conductors proved for the most part abortive. Edison himself worked for nearly two years on a lamp based upon the old idea of incandescent platinum strips or wires, but without success. The announcement of this lamp caused a heavy drop in gas shares long before the problem was really solved by a masterly stroke in his carbon filament lamp. Curiously, the nearest approach to the carbon filament lamp had been made in 1845 by Starr, an American, who described in a British patent specification a lamp in which electric current passed through a thin strip of carbon, kept it heated white when surrounded by a glass bulb in which a vacuum was maintained. Starr had exhibited his lamps to Faraday in England and was preparing to construct dynamos to furnish electric current for them in place of batteries, but sudden death put an end to his labors. The specification describing his lamp is perhaps the earliest description of an incandescent lamp of any promise, and the subsequently recorded ideas of inventors up to the work of Edison seem now almost in the nature of retrograde movements. None of them was successful commercially. Starr, who was only 25 years of age, is reported to have died of overwork and worry in his efforts to perfect his invention. His ideas were evidently far in advance of his time.

The Edison lamp differed from those which preceded it in the extremely small section of the carbon strip rendered hot by the current and in the perfection of the vacuum in which it was mounted. The filament was first made of carbonized paper and afterwards of bamboo carbon. The modern incandescent lamp has for years past been provided with a filament made by a chemical process. The carbon formed is exceedingly homogeneous and of uniform electric resistance. Edison first exhibited his lamp in his laboratory at Menlopark, N. J., in December, 1879, but before it could be properly utilized an enormous amount of work had to be done. His task was not merely the improvement of an art already existing, it was the creation of a new art. Special dynamo machines had to be invented and constructed for working the lamps, switches were needed for connecting and disconnecting lamps and groups of lamps, meters for measuring the consumption of electric energy were wanted, safety fuses and cut-offs had to be provided, electroliers, or fixtures, to support the lamps were required, and, lastly, a complete system of underground mains with appurtenances was a requisite for city plants.

Even the steam engines for driving the dynamos had to be remodeled and improved for electric work, and ten years of electric lighting development did more toward the refinement and perfection of steam engines than fifty years preceding. Steadiness of lights meant the preservation of steady speed in the driving machinery. The Pearl Street station, in New York City, was the first installation for the supply of current for incandescent lighting in a city district. The constant-pressure dynamos were gradually improved and enlarged. The details of all parts of the system were made more perfect, and in the hands of Edison and others the incandescent lamps, originally of high cost, were much cheapened and the quality of the production was greatly improved. Lamps originally cost $1 each. The best lamps that are made can be had at present for about one-fifth that price. Millions of incandescent lamps are annually manufactured. Great lighting stations furnish the current for the working of these lamps, some stations containing machinery aggregating many thousands of horsepower capacity. Not only do these stations furnish electric energy for the working of arc lamps and incandescent lamps, but in addition for innumerable motors ranging in size from the small desk fan of one-tenth horsepower up to those of hundreds of horsepower. The larger sizes replace steam or hydraulic power for elevators, and many are used in shops or factories for driving machinery, such as printing presses, machinery tools, and the like.

In spite of the fact that it was well known that a good dynamo when reversed could be made a source of power, few electric motors were in use until a considerable time after the establishment of the first lighting stations. Even in 1884, at the Philadelphia Electrical Exhibition, only a few electric motors were shown. Not until 1886 or thereafter did the "motor load" of an electric station begin to be a factor in its business success. The motors supplied are an advantageous adjunct, inasmuch as they provide a day load, increasing the output of the station at a time when the lighting load is small and when the machinery in consequence would, without them, have to remain idle. The growth of the application of electric motors in the closing years of the century has been phenomenal, even leaving out of consideration their use in electric railways.

Twenty years ago an electric motor was a curiosity; fifty years ago crude examples run by batteries were only to be occasionally found in cabinets of scientific apparatus. Machinery Hall at the Centennial Exhibition of 1876 typified the mill of the past, never again to be reproduced, with its huge engines and lines of heavy shafting and belts conveying power to the different tools or machines in operation. The modern mill or factory has its engines and dynamos located wherever convenient, its electric lines and numerous motors connected thereto, and each of them either driving comparatively short lines of shafting or attached to drive single pieces of machinery. The wilderness of belts and pulleys which used to characterize a factory is gradually being cleared away and electric distribution of power substituted. Moreover, the lighting of the modern mill or factory is done from the same electric plant which distributes power.

The electric motor has already partly revolutionized the distribution of power for stationary machinery, but as applied to railways in place of animal power the revolution is complete. The period which has elapsed since the first introduction of electric railways is barely a dozen years. It is true that a few tentative experiments in electric traction were made some time in advance of 1888, notably by Siemens, in Berlin, in 1879 and 1880, by Stephen D. Field, by T. A. Edison at Menlopark, by J. C. Henry, by Charles A. Van Depoele, and others. If we look further back, we find efforts, such as that of Farmer in 1847, to propel railway cars by electric motors driven by current from batteries carried on the cars. These efforts were of course doomed to failure for economical reasons. Electric energy from primary batteries was too costly, and if it had been cheaper the types of electric motor used yielded so small a return of power for the electric energy spent in driving them that commercial success was out of the question. These early efforts were, however, instructive, and may now be regarded as highly suggestive of later work. Traction by the use of storage batteries carried on an electric car has been tried repeatedly, but appears not to be able to compete with systems of direct supply from electric lines. The plan survives, however, in the electric automobiles, many of which have been put into service within a year or two. The electric automobile is not well fitted for country touring; it is best adapted to cities, where facilities for charging and caring for the batteries can be had. However, the electric carriage is of all automobile carriages the most easily controlled, most ready; it emits no smell or hot gases and is nearly noiseless.

About 1850 Hall, a well-known instrument maker of Boston, catalogued a small toy electric locomotive dragging a car upon rails which were insulated and connected with a stationary battery of two Grove cells. This arrangement was sold as a piece of a scientific apparatus, and appears to be the first example of an electrically driven vehicle connected by rolling contacts to an immovable energy source. Other early experimenters, such as Siemens, Field, and Daft, subsequently to Hall, used in actual railway work the supply by insulated tracks. This was supplanted later by overhead insulated wires or by the insulated third rail. Siemens & Halske, of Berlin, used a special form of overhead supply in 1881, and during the electrical exhibition in Paris in that year a street tramway line was run by them. Later Edison experimented with a third rail supply line at Menlopark, and at Portrush, in Ireland, an actual railway was put into operation by Siemens & Halske using the third rail system. This was about 1883. The power of the Portrush railway was that of a water wheel driving the generating dynamo.

The modern overhead trolley, or underrunning trolley, as it is called, seems to have been first invented by Van Depoele, and used by him in practical electric railway work about 1886 and thereafter. The universality of this invention for overhead supply marks the device as a really important advance in the art of electric traction. Van Depoele was also a pioneer in the use of an underground conduit, which he employed successfully in Toronto in 1884. The names of Edward M. Bentley and Walter H. Knight stand out prominently in connection with the first use of an underground conduit, tried under their plans in August, 1884, at Cleveland, on the tracks of the horse railway company.

We have barely outlined the history of the electric motor railway up to the beginning of a period of wonderful development resulting in the almost complete replacement by electric traction of horse traction or tramway lines, all within an interval of scarcely more than ten years.

The year 1888 may be said to mark the beginning of this work. In that year the Sprague Company, with Frank J. Sprague at its head, put into operation the electric line at Richmond, Va., using the underrunning trolley. Mr. Sprague had been associated with Edison in early traction work, and was well known in connection with electric motor work in general. The Richmond line was the first large undertaking. It had about 13 miles of track, numerous curves, and grades of from 3 to 10 per cent. The enterprise was one of great hardihood, and but for ample financial backing and determination to spare no effort or expenditure conducive to success, must certainly have failed. The motors were too small for the work, and there had not been found any proper substitute for the metal commutator brushes on the motors—a source of endless trouble and of an enormous expense for repairs. Nevertheless, the Richmond installation, kept in operation as it was in spite of all difficulties, served as an object lesson and had the effect of convincing Mr. Henry M. Whitney and the directors of the West End Street Railway of Boston of the feasibility of equipping the entire railway system of Boston electrically. Meanwhile the merging of the Van Depoele and Bentley-Knight interests into the Thomson-Houston Electric Light Company brought a new factor into the field, the Sprague interests being likewise merged with the Edison General Electric Company.

The West End Company, with 200 miles of track in and around Boston, began to equip its lines in 1888 with the Thomson-Houston plant. The success of this great undertaking left no doubt of the future of electric traction. The difficulties which had seriously threatened future success were gradually removed.

The electric railway progress was so great in the United States that about January 1, 1891, there were more than 240 lines in operation. About 30,000 horses and mules were replaced by electric power in the single year of 1891. In 1892 the Thomson-Houston interests and those of the Edison General Company were merged in the General Electric Company, an event of unusual importance, as it brought together the two great competitors in electric traction at that date. Other electric manufacturers, chief among which was the Westinghouse Company, also entered the field and became prominent factors in railway extension. In a few years horse traction in the United States on tramway lines virtually disappeared. Many cable lines were converted to electric lines, and projects such as the Boston Subway began to be planned. Not the least of the advantages of electric traction is the higher speed attainable with safety. The comfort and cleanliness of the cars, lighted brilliantly at night and heated in winter by the same source of energy which is used to propel them, are important factors.

All these things, together with the great extension of the lines into suburban and country districts, and the interconnection of the lines of one district with those of another, can not fail to have had a decidedly beneficial effect upon the life, habits, and health of the people. While the United States and Canada have been and still are the theater of the enormous electric advance in electric traction, as in other electric works, many electric car lines have in recent years been established in Great Britain and on the Continent of Europe. Countries like Japan, Australia, South Africa, and South America have also in operation many electric trolley lines, and the work is rapidly extending. Most of this work, even in Europe, has been carried out either by importation of equipment from America or by apparatus manufactured there, but following American practice closely. The bulk of the work has been done with the overhead wire and under running trolley, but there are notable instances of the use of electric conductors in underground slotted conduits, chief of which are the great systems of street railway in New York City.

In Chicago the application of motor cars in trains upon the elevated railway followed directly upon the practical demonstration at the World's Fair of the capabilities of third-rail electric traction on the Intramural Elevated Railway, and the system is rapidly extending so as to include all elevated city roads. A few years will doubtless see the great change accomplished.

The motor car, or car propelled by its own motors, has also been introduced upon standard steam roads to a limited extent as a supplement to steam traction. The earliest of these installations are the one at Nantasket, Mass., and that between Hartford and New Britain, in Connecticut. A number of special high-speed lines using similar plans have gone into operation in recent years. The problem of constructing electric motors of sufficient robustness for heavy work and controlling them effectively was not an easy one, and the difficulties were increased greatly because of the placing of the motors under the car body, exposed to wet, to dust, and dirt of road. The advantage of the motor car or motor-car train is that the traction or hold upon the track increases with the increase of the weight or load carried. It is thus able to be accelerated rapidly after a stop and also climb steep grades without slipping its wheels. Nevertheless there are circumstances which favor the employment of a locomotive at the head of a train, as in steam practice. This is the case in mines where trains of coal cars or ore cars are drawn by electric mining locomotives. Many such plants are in operation, and at the same time the electric power is used to drive fans for ventilating, pumps for drainage, electric hoists, etc., besides being used for lighting the mines. The trains in the tunnels of the Metropolitan Underground Railway of London have for many years been operated by steam locomotives, with the inevitable escape of steam, foul, suffocating gases, and more or less soot.

A number of years ago the tunnel of the City and South London Railway was put into successful operation with electric locomotives drawing the trains of cars, and the nuisance caused by steam avoided. This work recalls the early efforts of Field, of Daft, and Bentley & Knight in providing an electric locomotive for replacing the steam plant of the elevated roads in New York City. Well conceived as many of these plans were, electric traction had not reached a sufficient development, and the efforts were abandoned after several more or less successful trials. It is now seen that the motor-car train may advantageously replace the locomotive-drawn train in such instances as these elevated railways.

The three largest and most powerful electric locomotives ever put into service are those which are employed to take trains through the Baltimore and Ohio Railroad tunnel at Baltimore. They have been in service about seven or eight years, and are fully equal in power to the large steam locomotives used on steam roads. Frequently trains of cars, including the steam locomotive itself, are drawn through the tunnel by these huge electric engines, the fires on the steam machines being for the time checked so as to prevent fouling the air of the tunnel. There was opened in London in 1900 a new railway, called the Central Underground, equipped with twenty-six electric locomotives for drawing its trains. The electric and power equipment, which embodied in itself the latest results of American practice, was also manufactured in America to suit the needs of the road. Other similar railways are in contemplation in London and in other cities of Europe. As on the elevated roads in New York City, the replacement of underground steam traction, where it exists, by electric traction is evidently only a question of a few years.

An electric railway may exemplify a power transmission system in which power is delivered to moving vehicles. But the distances so covered are not generally more than a few miles from the generating station. Where, however, abundant water power exists, as at Niagara, or where fuel is very expensive and power is to be had only at great distances from the place at which it is to be used, electricity furnishes the most effective means for transmission and distribution. Between the years 1880 and 1890 the device called the alternating current transformer was developed to a considerable degree of perfection. It is in reality a modified induction coil, consisting of copper wire and iron, whereby a current sent through one of its coils will induce similar currents in the other coils of apparatus. It has the great advantage of having no moving parts. Faraday, in 1831, discovered the fundamental principle of the modern transformer. Not only, however, will the current in one coil of the apparatus generate by induction a new current in an entirely separate coil or circuit, but by suitably proportioning the windings we may exchange, as it were, a large low-pressure current for a small but high-pressure current, or vice versa. This exchange may be made with a very small percentage of loss of energy. These valuable properties of the transformer have rendered it of supreme importance in recent electrical extension. The first use made of it, in 1885–86, was to transform a high-pressure current into one of low pressure in electric lighting, enabling a small wire to be used to convey electric energy at high pressure and without much loss to a long distance from the station. This energy at high pressure reaches the transformer placed within or close to the building to be lighted. A low-pressure safe current is conveyed from the transformer to the wires connected to the lamps. In this way a current of 2,000 volts, an unsafe and unsuitable pressure for incandescent lighting, is exchanged for one of about 100 volts, which is quite safe. In this way also the supply station is enabled to reach a customer too far away to be supplied directly with current at 100 volts without enormous expense for copper conductors.

The alternating current transformer not only greatly extended the radius of supply from a single station, but also enabled the station to be conveniently located where water and coal could be had without difficulty. It also permitted the distant water powers to become sources of electric energy for lighting, power, or for other service. For example, a water power located at a distance of 50 to 100 miles or more from a city or from a large manufacturing center where cost of fuel is high may be utilized as follows: A power station will be located upon the site of the water power and the dynamos therein will generate electricity at, say, 2,000 volts pressure. By means of step-up transformers this will be exchanged for a current of 30,000 volts for transmission over a line of copper or aluminum wire to the distant consumption area. Here there will be a set of step-down transformers which will exchange the 30,000 volt line current for one of so low a pressure as to be safe for local distribution to lamps, to motors, etc., either stationary or upon a railway. The same transmission plant may simultaneously supply energy for lighting, for power, for heat, and for charging storage batteries. It may therefore be employed both day and night.

These long-distance power-transmission plants are generally spoken of as "two-phase," "three-phase," or "polyphase" systems. Before 1890 no such plants existed. A large number of such installations are now working over distances of a few miles up to 100 miles. They differ from what are known as single-phase alternating systems in employing, instead of a single alternating current, two, three, or more, which are sent over separate lines, in which the electric impulses are not simultaneous, but follow each other in regular succession, overlapping each other's dead points, so to speak. Early suggestions of such a plan, about 1880 and thereafter, by Baily, Deprez, and others bore no fruit, and not until Tesla's announcement of his polyphase system in 1888 was much attention given to the subject. A widespread interest in Tesla's work was invoked, but several years elapsed before engineering difficulties were overcome. This work was done mainly by the technical staffs of the large manufacturing companies, and it was necessary to be done before any notable power transmissions on the polyphase system could be established. After 1892 the growth became very rapid.

The Falls of Niagara early attracted the attention of engineers to the possibility of utilizing at least a fraction of the power. It was seen that several hundred thousand horsepower might be drawn from it without materially affecting the fall, itself equivalent to several millions of horsepower. A gigantic power station has lately been established at Niagara, taking water from a distance above the falls and delivering it below the falls through a long tunnel, which forms the tailrace. Ten water wheels, located in an immense wheel pit about 200 feet deep, each wheel of a capacity of 5,000 horsepower, drive large vertical shafts, at the upper end of which are located the large two-phase dynamos, each of 5,000 horsepower. The electric energy from these machines is in part raised in pressure by huge transformers for transmission to distant points, such as the city of Buffalo, and a large portion is delivered to the numerous manufacturing plants located at moderate distances from the power station. Besides the supply of energy for lighting and for motors, including railways, other recent uses of electricity to which we have not yet alluded are splendidly exemplified at Niagara. Davy's brilliant discovery of the alkali metals, sodium and potassium, at the opening of the century, showed the great chemical energy of the electric current. Its actions were afterwards carefully studied, notably by the illustrious Faraday, whose discoveries in connection with magnetism and magneto-electricity have been briefly described. The electric current was found to act as a most potent chemical force, decomposing and recomposing many chemical compounds, dissolving and depositing metals. Hence early in the century arose the art of electroplating of metals, such as electro-gilding, silver-plating, nickel-plating, and copper deposition, as in electrotyping. These arts are now practiced on a very large scale, and naturally have affected the whole course of manufacturing methods during the century. Moreover, since the introduction of dynamo current electrolysis has come to be employed in huge plants, not only for separating metals from each other, as in refining them, but in addition for separating them from their ores, for the manufacture of chemical compounds before unknown, and for the cheap production of numerous substances of use in the various arts on a large scale. Vast quantities of copper are refined and silver and gold often obtained from residues in sufficient amount to pay well for the process.

At Niagara also are works for the production of the metal aluminum from its ores. Similar works exist at other places here and abroad where power is cheap. This metal, which competes in price with brass, bulk for bulk, was only obtainable before its electric reduction at $25 to $30 per pound. The metal sodium is also extracted from soda. A large plant at Niagara also uses the electric current for the manufacture of chlorine for bleach, and caustic soda, both from common salt. Chlorate of potassium is also made at Niagara by electrolysis. The field of electro-chemistry is indeed full of great future possibilities. Large furnaces heated by electricity, a single one of which will consume more than a thousand horsepower, exist at Niagara. In these furnaces is manufactured from coke and sand, by the Acheson process, an abrasive material called carborundum, which is almost as hard as diamond, but quite low in cost. It is made into slabs and into wheels for grinding hard substances. The electric furnace furnishes also the means for producing artificial plumbago, or graphite, almost perfectly pure, the raw material being coke powder.

A large amount of power from Niagara is also consumed for the production in special electric arc furnaces of carbide of calcium from coke and lime. This is the source of acetylene gas, the new illuminant, which is generated when water is brought into contact with the carbide. The high temperature of the electric furnace thus renders possible chemical actions which under ordinary furnace heat would not take place. Henri Moissan, a French scientist, well known for his brilliant researches in electric furnace work, has even shown that real diamonds can be made under special conditions in the electric furnace. He has, in fact, probably practiced in a small way what has occurred on a grand scale in nature, resulting in diamond fields such as those at Kimberley. One less problem is thus left to be solved. The electro-chemical and kindred arts are practiced, not alone at Niagara, but at many other places where power is cheap. Extensive plants have grown up, mostly within the five years before the close of the century. All of the great developments in this field have come about within the last decade.

The use of electricity for heating is not confined to electric furnaces, in which the exceedingly high temperature obtainable is the factor giving rise to success. While it is not likely that electricity will soon be used for general heating, special instances, such as the warming of electric cars in winter by electric heaters, the operation of cooking appliances by electric current, the heating of sad-irons and the like, give evidence of the possibilities should there ever be found means for the generation of electric energy from fuel with such high efficiency as 80 per cent or more. Present methods give, under most favorable conditions, barely 10 per cent, 90 per cent of the energy value of the fuel being unavoidably wasted.

Another application of the heating power of electric currents is found in the Thomson electric welding process, the development of which has practically taken place in the past ten years. In this process an exceedingly large current, at very low electric pressure, traverses a joint between two pieces of metal to be united. It heats the joint to fusion or softening; the pieces are pushed together and welded. Here the heat is generated in the solid metal, for at no time during the operation are the pieces separated. The current is usually obtained from a welding transformer, an example of an extreme type of stepdown transformer. Current at several hundred volts passed into the primary winding is exchanged for an enormous current at only 2 or 3 volts in the welding circuit in which the work is done. The present uses of this electric welding process are numerous and varied. Pieces of most of the metals and alloys before regarded as unweldable are capable of being joined, not only to pieces of the same metal, but also to different metals. Electric welding is applied on the large scale for making joints in wires or rods, for welding wagon and carriage wheel tires, for making barrel hoops and bands for pails, for axles of vehicles, and for carriage framing. It has given rise to special manufactures, such as electrically welded steel pipe or tube, wire fencing, etc. It is used for welding together the joints of street-car rails, for welding teeth in saws, for making many parts of bicycles, and in tool making. An instance of its peculiar adaptability to unusual conditions is the welding of the iron bands embedded within the body of a rubber vehicle tire for holding the tire in place. For this purpose the electric weld has been found almost essential.

Another branch of electric development concerns the storage of electricity. The storage battery is based upon principles discovered by Gaston Planté, and applied since 1881 by Brush, by Faure, and others. Some of the larger lighting stations employ as reservoirs of electric energy large batteries charged by surplus dynamo current. This is afterwards drawn upon when the consumer's load is heavy, as during the evening. The storage battery is, however, a heavy, cumbrous apparatus, of limited life, easily destroyed unless guarded with skill. If a form not possessing these faults be ever found, the field of possible application is almost limitless.

There is no space here to deal with the developments of the use of electricity in the employment of the physiological powers of the electrical current which have given rise to the science of electro-therapeutics. It is probably true that electricity is finally to be one of the most potent agencies in the treatment of disease and in the alleviation of human suffering; but unfortunately the name "electricity" is often made use of by the quack and charlatan to put forward wares in the form of electric belts, electric insoles, electric combs, and what not, the effect of which is absolutely nil except in the imagination of the user. There are also devices which do, in fact, produce slight electrical effects, which are paraded as panaceas for serious ills, when in reality their electrical effects amount to nothing and their therapeutic value is less than nothing.

There is no space, either, to dilate upon the possibilities in an artistic way which have arisen in the development of electricity for lighting. Magnificent effects, scenic and otherwise, are now within the reach of the artist. The great international expositions have in late years been characterized by the profusion of such effects depending on electricity.

The above by no means complete account of the progress in electric applications during the century just closed should properly be supplemented by an account of the accompanying great advances regarded from the purely scientific aspect. It is, however, only possible to make a brief reference thereto within the limits of this article. The scientific study of electricity and the application of mathematical methods in its treatment have kept busy a host of workers and drawn upon the resources of the ablest minds the age has produced. Gauss, Weber, Ampère, Faraday, Maxwell, and Helmholtz are no longer with us. Of the early founders of the science we have yet such men as Lord Kelvin, formerly Sir William Thomson, Mascart, and others, still zealous in scientific work. Following them are a large number notable for valuable contributions to the progress of electrical science, in discoveries, in research, and in mathematical treatment of the various problems presented. Modern magnetism took form in the hands of Rowland, Hopkinson, Ewing, and many other able workers.

Has science any answer to make to the question, What is electricity? We think not; nor has it any answer to make to the question, What is energy? The most that science can possibly expect to do is to extend our horizon and permit us to acquire a deeper knowledge of the intimate relations of things. We speak of the ether as the electrical medium, and we acquire more and more knowledge of its properties and actions as the years go by. Facts are gradually being accumulated by workers in all departments of science, and there must follow generalizations which will bring into harmony the present discordancies where they appear. It will probably be found that the electrical properties of the ether are the fundamental ones on which the universe is built and that the properties of matter, which we speak of as mass, weight, inertia, cohesion, elasticity, etc., are dependent upon or have their origin in the ether properties. Perhaps, just as light and radiant heat have been shown to be electrical vibrations, gravitation and the other properties may follow. True it is that electrical laws are most simple, most definite. Electrical measurements can be made with the utmost accuracy and delicacy. Indications these are of its fundamental and universal character.

In order to account for the passage of light, radiant heat, magnetism, and other forces through space science has need of what is called the ether, a medium filling all space and propagating waves of heat and light, as well as magnetic disturbances and gravitation. The sun radiates to the earth luminous waves and heat waves. Moreover, it has been shown that whenever there is a great cyclonic storm upon the sun the earth sympathizes or receives influences which disturb the compass needle. There is reason to believe that the eleven-year sun spot periods find their expression upon the earth in the greater frequency of displays of aurora borealis, magnetic storms, and even thunderstorms following the more active storm period of the sun, when the sun spots are most numerous.

What, then, is the nature of this ether of space? To this question no complete answer can as yet be given, except to say that it is the electro-magnetic medium. It is the ether and not the air which enables a magnet to attract or repel, for the action occurs in the best vacuum, undiminished. It is the ether and not the air which enables an electrified body to act upon surrounding bodies in attracting or repelling them. When we sit in front of an open fire, it is the ether which brings the light and also the heat radiated to us. Early in the century the theory that light consisted of ether vibrations of a particular character became the commonly accepted theory. It remained for Clerk Maxwell, a mathematical physicist of the highest eminence, to put forward, about the middle of the century, the idea that light waves were really electrical waves. Light would, then, become one form of the manifestation of electrical force; and the same would be true of radiant heat. This theory, however, lacked experimental confirmation until the researches of the late Dr. Hertz, too early lost to science. We see references to what are called "Hertzian waves." These are waves identical in nature with light waves, but of much lower pitch or period. Red light consists of about four hundred millions of millions of electrical waves in the ether per second; blue or violet light about double that number. Hertz showed in his experiments that electric sparks between polished balls, under proper conditions, were attended by ether waves of the same nature as those of light, but having a pitch represented by some millions of vibrations per second. These waves, however, could be reflected, could be refracted, could be polarized, and be dealt with as if they were light waves. Ordinary alternating-current waves are, in fact, closely akin to these waves, only their speed is from 25 to 200 or 300 per second. Their "frequency" is low.

When we speak of "high-frequency waves" we usually mean waves of great rapidity as compared with ordinary alternating-current waves. When a Leyden jar is discharged through a short wire, or coil of wire, there is momentarily generated a set of high-frequency waves. This was shown by Henry in the early half of the century. The brilliant effects which have been produced within recent years by Mr. Tesla, as well as by the present writer, in the use of high-frequency discharges or waves are well known. Electric sparks many feet in length are easily generated. Astonishing luminous effects accompany high-frequency experiments. Conductors glow in the dark with a bluish luminosity. Vacuum tubes are caused to give out light many feet away from the apparatus in which the high-frequency discharges are generated.

Most curious perhaps of all, to the lay mind, is the possibility of passing through the body current enough at high frequency to light lamps in circuit with the body, without producing any harmful effects, and, in fact, without producing any sensation whatever. Spark discharges from the apparatus which would seem to have the power to kill instantly are received harmlessly. Indeed, when currents have a frequency more than a certain amount—say 10,000 per second—the physiological effects seem to be in abeyance, as if the rapid reversals of the current could not leave any permanent effect.

Certain forms of moderately high frequency currents give promise of actually producing insensibility to pain without interfering with consciousness, and it is possible that the future may see surgical operations performed with the protection of the subject from painful sensations by the passage of these currents. Up to the present, however, there has been no use actually made in the practice of high-frequency effects, unless we class with such effects those of transmission without wires.

Wireless telegraphy of to-day is, however, a direct outcome of Hertz's experiments on electric waves. It is but little more than ten years since Hertz announced his results to the world. His work, supplemented by that of Branly, Lodge, and more recently Marconi, has made wireless telegraphy a possibility, and there are indications that enormous distances may yet be covered by this ethereal transmission. Just here we may refer to the fact—for it is a fact—that the electrical energy transmitted over a line, which may be many miles in length, really does not travel by the wire connecting the two points. It travels in the ether surrounding the wire. The wire itself is, in fact, the guiding core of the disturbances in the ether which proceed outward in all directions to unlimited distances. The guiding core or conducting wire is needed to focalize or direct the delivery of the energy. This curious conclusion of science, then, that the power from the power-station wire travels in the space around the wires led from the station is one of the results of recent electrical studies, just as with light those studies begun by Maxwell and Hertz have led to the inevitable conclusion that the light of the candle, the light of a kerosene lamp, and the light of a gas burner are all in essence electrical phenomena, as are all forms of radiation in the ether.

The wireless telegraph of to-day utilizes a sudden electrical disturbance made at one point, which travels by the surrounding ether in all directions and is picked up in feeble fashion, it may well be, by very sensitive receiving instruments. The shock or disturbance to the ether is thus recognized, and by a preconcerted system of signals the slight disturbances are sent out in a sequence such as to convey intelligible messages. Distances of upward of 100 miles are thus covered with what must be regarded as an extremely feeble means so far as the scale of the apparatus is concerned, and there would seem to be no reason why the scale of operations greatly increased may not in the near future widely extend the range over which wireless telegraphy can work.

The wonderful X ray and the rich scientific harvest which has followed the discovery by Röntgen of invisible radiation from a vacuum tube were preceded by much investigation of the effects of electric discharges in vacuum tubes, and Hittorf, followed by Crookes, had given special study to these effects in very high or nearly perfect vacua. Crookes, though specially enriching science by his work, missed the pecular X ray, which nevertheless must have been emitted from his vacuum tubes, not only in his hands, but in those of subsequent students. It was as late as 1896 that Röntgen announced his discovery. Since that time several other sources of invisible radiation have been discovered, more or less similar in effect to the radiations from a vacuum tube, but emitted, singular as the fact is, from rare substances extracted from certain minerals. Leaving out of consideration the great value of the X ray to physicians and surgeons, its effect in stimulating scientific inquiry has almost been incalculable. The renewed study of effects of electric discharge in vacuum tubes has already, in the work of such investigators as Lenard, J. J. Thomson, and others, apparently carried the subdivision of matter far beyond the time-honored chemical atom, and has gone far toward showing the essential unity of all the chemical elements. It is as unlikely that the mystery of the material universe will ever be completely solved as it is that we can gain an adequate conception of infinite space or time. But we can at least extend the range of our mental vision of the processes of nature as we do our real vision into space depths by the telescope and the spectroscope. There can now be no question that electric conditions and actions are more fundamental than many hitherto so regarded.

The nineteenth century closes with many important problems in electrical science as yet unsolved. What great or far-reaching discoveries are yet in store, who can tell? What valuable practical developments are to come, who can predict? The electrical progress has been great—very great—but after all only a part of that grander advance in so many other fields. The hands of man are strengthened by the control of mighty forces. His electric lines traverse the mountain passes as well as the plains. His electric railway scales the Jungfrau. But he still spends his best effort, and has always done so, in the construction and equipment of his engines of destruction, and now exhausts the mines of the world of valuable metals for ships of war, whose ultimate goal is the bottom of the sea. In this, also, electricity is made to play an increasingly important part. It trains the guns, loads them, fires them. It works the signals and searchlights. It ventilates the ship, blows the fires, and lights the dark spaces. Perhaps all this is necessary now, and, if so, well. But if a fraction of the vast expenditure entailed were turned to the encouragement of advance in the arts and employments of peace in the coming century, can it be doubted that, at the close, the nineteenth century might come to be regarded, in spite of its achievements, as a rather wasteful, semibarbarous transition period?

THE PHOTOGRAPHY OF SOUND WAVES AND THE DEMONSTRATION OF THE EVOLUTIONS OF REFLECTED WAVE FRONTS WITH THE CINEMATOGRAPH.[1]

By R. W. Wood.

INTRODUCTION.

In a paper published in the Philosophical Magazine for August, 1899, I gave an account of some experiments on the photography of sound waves, and their application in the teaching of optical phenomena. Since writing this paper I have extended the work somewhat, and at a meeting of the Royal Society, on February 15, 1900, gave an account of this work and demonstrated certain features of wave motion with the cinematograph.

In the present article I propose to give a somewhat more extended account of the work, paying especial attention to the analogies between the sound waves and waves of light.

In teaching the subjects of optics we are obliged to resort to diagrams when dealing with the wave front, and in spite of all that we can do the student is apt to form the opinion that the rays are the actual entities, and that wave fronts are after all merely conceptions.

The set of photographs illustrating this article will, I think, be of no small use to teachers in ridding the minds of students of the obnoxious rays, and impressing the fact that all of the common phenomena of reflection, refraction, and diffraction are due simply to changes wrought on the wave front.

Sound waves in air were first observed and studied by Toepler, by means of an exceedingly sensitive optical contrivance for rendering visible minute changes in the optical density of substances. A very full description of the device will be found in Toepler's article (Wied. Annalen, cxxxi), while a brief account of it will be given presently.

The waves in question are the single pulses of condensed air given out by electric sparks. A train of waves would complicate matters too much, and for illustrating the optical phenomena which we are to take up would be useless.

The snap of the spark gives us just what we require, namely, a single wave front, in which the condensation is considerable.

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[1] Reprinted from Nature, No. 1606, vol. 62, August 9, 1900.

When seen subjectively, as was the case in Toepler's experiments, the wave fronts, if at all complicated, as they often are, can not be studied to advantage, as they are illuminated for an instant only and appear in rapid succession in different parts of the field. By the aid of photography a permanent record of the forms can be obtained and studied at leisure. The first series of photographs, published in the Philosophical Magazine, were made with an apparatus similar to the one to be presently described; while most of those illustrating this article were made on a much larger scale by employing a large silvered mirror in place of the lens, an improvement due to Professor Mach, of Prague, who has given much attention to the subject.

As it is a matter of no trouble at all to set up in a few minutes, in any physical laboratory, an apparatus for showing the air waves subjectively, and as the method does not seem to be as well known as it deserves to be, a brief description of the "Schlieren" apparatus, as Toepler named it, may not be out of place.

THE APPARATUS.

The general arrangement of the "Schlieren" apparatus is shown in figure 1. A good-sized achromatic lens of the finest quality obtainable, and of rather long focus, is the most important part of the device. I have been using the object glass of a small telescope figured by the late Alvan Clark. Its diameter is 5 inches, and the focal length about 6 feet. I have no doubt but that a smaller lens could be used for viewing the waves, but one of at least this size is desirable for photographing them.

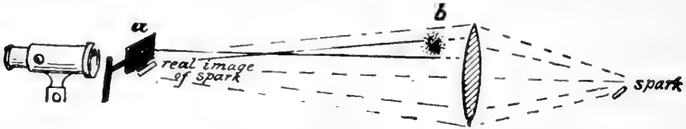

FIG. 1.

The lens is mounted in front of a suitable source of light (in tne present case an electric spark), which should be at such a distance that its image on the other side of the lens is at a distance of about 15 feet.

The image of the spark, which we will suppose to be straight, horizontal, and very narrow, is about two-thirds covered with a horizontal diaphragm (*a*), and immediately behind this is placed the viewing telescope. On looking into the telescope we see the field of the lens uniformly illuminated by the light that passes under the diaphragm, since every part of the image of the spark receives light from the whole lens. If the diaphragm be lowered, the field will darken; if it be raised, the illumination will be increased. In general it is best to have the diaphragm so adjusted that the lens is quite feebly illuminated, though this is not true for photographic work. Let us now suppose that there is a globular mass of air in front of the lens of slightly greater optical density than the surrounding air (*b*). The rays of light going through the upper portion of this denser mass will be bent down and will form an image of the spark below the diaphragm, allowing more light to enter the telescope from this particular part of the field; consequently on looking into the instrument we shall see the upper portion of the globular mass of air brighter than the rest of the field. The rays which traverse the under part of "*b*," however, will be bent up, on the contrary, forming an image of the spark higher up and wholly covered by the diaphragm; consequently this part of the field will appear black. It will be readily understood that with the long path between the lens and the image a very slight change in the optical density of any portion of the medium in front of the lens will be sufficient to raise or depress the image above or below the edge of the diaphragm, and will consequently make itself manifest in the telescope.

The importance of using a lens of first-class quality is quite apparent, since variations in the density of the glass of the lens will act in the same way as variations in the density of the medium before it and produce unequal illumination of the field. It is impossible to find a lens which will give an absolutely even, feeble illumination, but a good achromatic telescope objective is perfect enough for every purpose. A more complete discussion of the operation of the apparatus will be found in Toepler's original paper in the Annalen. The sound waves, which are regions of condensation and consequent greater optical density, make themselves apparent in the same way as the globular mass of air already referred to. They must be illuminated by a flash of exceedingly short duration, which must occur while the wave is in the field of view.

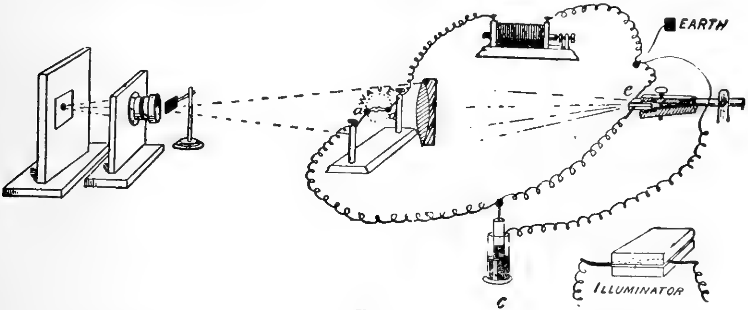

FIG. 2.

Toepler showed that this could be done by starting the sound wave with an electric spark and illuminating it with the flash of a second spark occurring a moment later, while the wave was still in the field. A diagram of the apparatus used is shown in fig. 2. In front of the lens are two brass balls (*a a*), between which the spark of an induction coil passes, immediately charging the Leyden jar *c*, which discharges across the gap at *e* an instant later. The capacity of the jar is so regulated that the interval between the two sparks is about one ten-thousandth of a second. The field of the lens is thus illuminated by the flash of the second spark before the sound wave started by the first spark has gone beyond the edge of the lens.

To secure the proper time interval between the two sparks it is necessary that the capacity of the jar be quite small. A good-sized test tube half full of mercury standing in a jar of mercury is the easiest arrangement to fit up. This limits the length and brilliancy of the illuminating spark, and with the device employed by Toepler I was unable to get enough light to secure photographs of the waves. After some experimenting I found that if the spark of the jar was passed between two thin pieces of magnesium ribbon pressed between two pieces of thick plate glass a very marked improvement resulted. With this form of illuminator I found that five or six times as much light could be obtained as by the old method of passing the spark between two brass balls.

The spark is flattened out into a band and is kept always in the same plane, the light issuing in a thin sheet from between the plates. By this arrangement we secure a light source of considerable length, great intensity, and bounded by straight edges, the three essentials for securing good results. The glass plates, with the ribbon terminals between them, must be clamped in some sort of a holder and directed so that the thin sheet of light strikes the lens. This can be accomplished by darkening the room, fastening a sheet of paper in front of the lens, and then adjusting the plates so that the paper is illuminated as much as possible. The image formed by the lens will be found to have very sharp straight edges,[1] on one of which the edge or the diaphragm can be set in such a manner as to allow but very little light to pass when the intervening medium is homogeneous. A very slight change, however, in any portion may be sufficient to cause the entire amount of light passing through that portion to pass below the diaphragm and enter the telescope.

The photographs were made by substituting a photographic objective for the telescope in the focal plane of which a vertical board was mounted to support the plate. The room was darkened, a plate held in position, and a single spark made to pass between the knobs by pulling a string connected with the hammer of the induction coil. The plate was then moved a trifle and a second impression secured in the same way. This obviated several of the difficulties experienced in the earlier work. The images never overlapped, and the hot air from the spark did not appear in the pictures. About thirty-five images were obtained on each plate in less than a minute, from which

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[1] If more than one image appears it means that the plane of the glass plates of the illuminator does not lie parallel to the optical axis of the system. It is of prime importance to secure a single image.

it was usually possible to pick a series showing the wave in all stages of its development, owing to the variations in the time interval between the two sparks.

In the first series the pictures were so small that it was necessary to enlarge them several diameters. Those of the new series, owing to the use of an 8-inch mirror in place of the 5-inch lens, and an objective of larger aperture and longer focus, required no enlarging.

THE WAVE-FRONT PHOTOGRAPHS.

In the study of optics we may treat the subject of regular reflection in two ways, by rays and by wave fronts. When spherical waves of light are reflected from a plane surface, we know that the reflected waves are also spherical in form, the center of curvature being a point just as far beneath the reflecting surface as the source of light is above it. In the first of the series of photographs we have the reflection of a spherical wave of sound by a flat plate of glass, the wave appearing as a circle of light and shade surrounding the image of the balls between which the spark passed (fig. 3, Pl. I). The reflected wave or echo from the plate is seen to be spherical, with a curvature similar to the incident wave.

When we have a source of light in the focus of a parabolic mirror, the rays leave the mirror's surface parallel to one another and move out in an intense narrow beam. Treating this case from the wave-front point of view, we ascertain by the usual geometrical construction that the spherical wave is changed by reflection into a plane or flat wave which moves out of the mirror without further divergence. In the picture (fig. 4, Pl. I) only a portion of the parabolic reflector is shown near the bottom. The sound wave starts in the focus, and the reflected portion appears quite flat.[1]

What happens now if we use a spherical mirror in the same way?

Owing to the spherical aberration the reflected rays are not strictly parallel, or the reflected wave is not a true plane. Let us start a sound wave in the focus of such a mirror, and follow the reflected portion out of the mirror (fig. 5, Pl. I). We notice that near the axis of the mirror the effect is much the same as in the case of the parabola—that is, the reflected front is plane. Thus we are accustomed to say that if we confine ourselves to a small area around the axis, a mirror of spherical form acts almost as well as a parabola. If, on the contrary, we consider the reflection from the entire hemisphere, we see that the reflected wave curls up at the edges, having a form not unlike a flat-bottomed saucer. The flat bottom moves straight up, traveling everywhere normal to its surface; but the curled up edges converge inward, coming to a focus in the form of a ring around the flat bottom. This

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[1] In this series and some others left and right have been inadvertently interchanged by the engraver. The series should be followed by the numbers.

ring, of course, does not show in the photograph, which is a sectional view, but it will be seen that in one of the views (No. 4) the curved edge has disappeared entirely. In reality it is passing through a ring focus, and presently it will appear again on the other side of the focus, curved the other way, of course, and trailing along after the flat bottom. This curious evolution of the wave can be shown by geometrical construction, and I shall show later how its development can be shown with the cinematograph.

When the spherical waves start in one focus of an elliptical mirror, they are transformed by reflection into converging spheres, which shrink to a point at the other focus, the surface being aplanatic for rays issuing from a point. An elliptical mirror was made by bending a strip (fig. 6, Pl. I) of metal into the required form, and a sound wave started at one of the foci. The transformation of the diverging into a converging sphere and the shrinkage of the latter to a point at the other focus are well shown (fig. 6).

We will consider next another case of spherical aberration. When parallel rays of light enter a concave mirror those reflected from points of the mirror near its axis converge approximately to a point situated halfway between the surface of the mirror and its center of curvature. The wave front in the case of parallel rays is, of course, plane and is changed by reflection into a converging shell of approximately spherical curvature. If we investigate the case more carefully, we find, however, that the reflected rays do not come accurately to a focus, but envelop a surface known as the caustic—in this case an epicycloid. The connection between the wave front and the caustic is perhaps not at once apparent. Let us examine the changes wrought on a sound wave entering a concave hemispherical mirror (fig. 7, Pl. II).

If we follow the wave during its entrance into the mirror, we see that the reflected portion trails along behind, being united to the unreflected part at the mirror's surface. After the reflection is complete we find the reflected wave of a form not unlike a volcanic cone with a large bowl-shaped crater (No. 4). This bowl-shaped portion we may regard as a converging shell, which shrinks to a point at the focus of the mirror. As it shrinks the steep sides of the cone run in under the bowl, crossing at about the moment when the converging portion is passing through the focus (No. 6). The rim of the crater forms a cusp on the wave front, and if we follow this cusp we shall see that it traces the caustic surface. Hence we may define the caustic as the surface traced by the cusp of the wave front.

The portion of the wave which comes to a focus at once begins to diverge again, uniting with the sides of the crater, the whole moving out of the mirror in a form somewhat resembling a mushroom or the bell of a Medusa jellyfish. The turned-under edges of the bell are

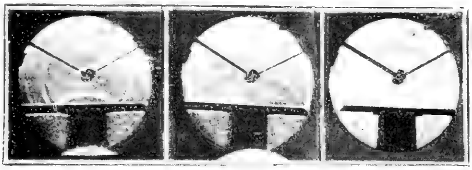

Fig. 3.

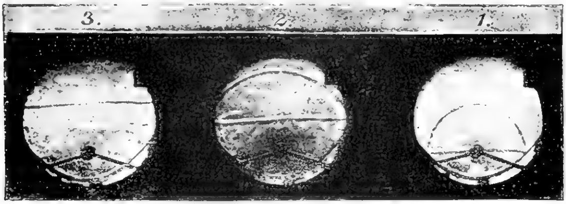

Fig. 4.

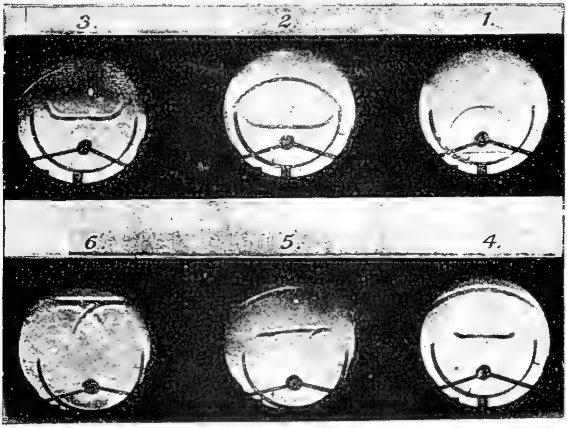

Fig. 5.

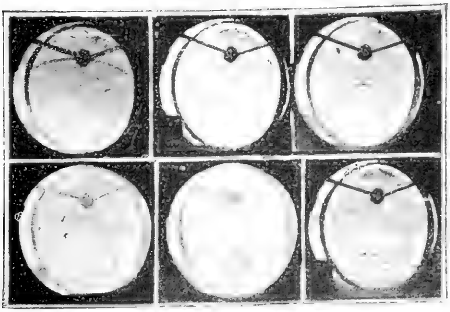

Fig. 6.

PHOTOGRAPHY OF SOUND WAVES.

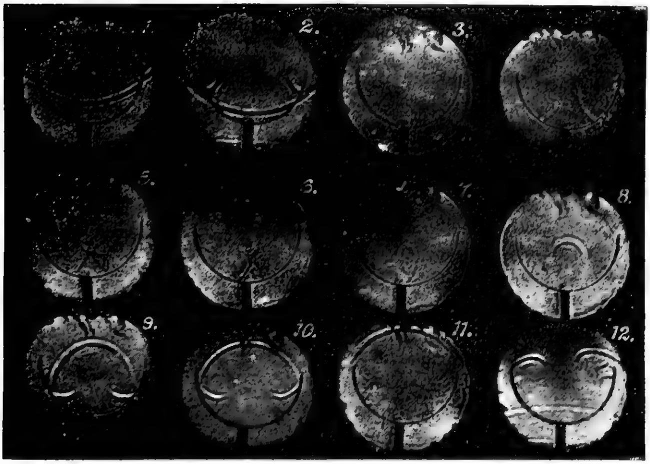

Fig. 7.

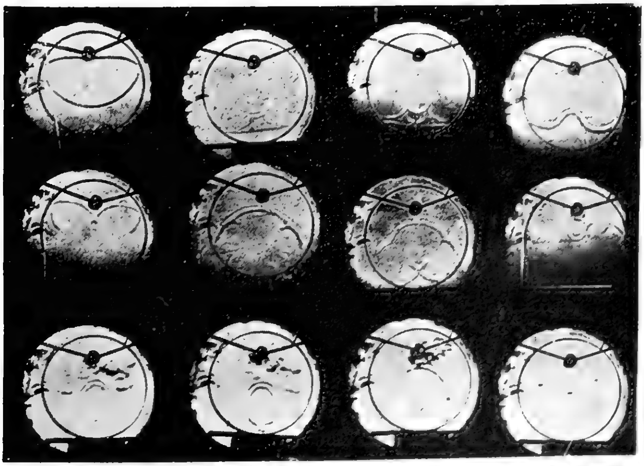

Fig. 8.

PHOTOGRAPHY OF SOUND WAVES.

cusped, and these cusps trace the caustic enveloped by the twice-reflected rays. These forms can also be constructed geometrically.

A much more complicated case is now shown (fig. 8, Pl. II). Here the wave starts within a complete sphere or rather cylinder. (Cylindrical surfaces have been used in all these cases for obvious reasons, the sectional views shown in the photographs being the same for both forms of surface.) Starting in the principal focus of the closed mirror, the wave is bounced back and forth, becoming more complicated after each reflection, yet always symmetrical about the axis. Only a few of the many forms are shown, and with the exception of the first three or four are not arranged in order; for at the time that the series were arranged on the slide this case had not been worked out geometrically, and it was quite impossible to determine the evolution of the different forms. More recently this case has been constructed for five reflections and all of the forms shown in the photographs found.

We will take up next some cases of refraction, the first being that of a spherical wave at a flat surface of a denser medium. In fig. 9, Pl. III, we have a rectangular tank with sides made of plane parallel glass and covered with a collodion film of soap-bubble thickness made by the method described by Toepler. Ordinary collodion is diluted with about ten parts of ether, poured on a small piece of plate glass, and immediately drained off. As soon as it is quite dry a rectangle is cut with a sharp knife on the film. Toepler's method of removing the film was to place a drop of water on one of the cuts and allow it to run in by capillarity, but I have had better success by proceeding in the following manner: One end of the plate is lowered into a shallow dish of water and the plate inclined until the water comes up to one of the cuts. By looking at the reflection of a window in the water it is possible to see whether the film commences to detach itself from the glass. If all goes well, it will float off on the surface of the water along the line of the knife cut, and it should be slowly lowered (one end resting on the bottom of the dish) until the rectangular piece detaches itself and floats freely on the surface. The edges of the tank are well greased, and then lowered carefully upon the film, to which they will adhere. The whole must then be lifted from the water in an oblique direction, when the film will be found covering the tank and exhibiting the most beautiful interference colors. The tank was filled with carbonic acid and placed under the origin of the sound wave. On striking the collodion film the wave is partly reflected and partly transmitted, and it will be seen that the reflected component in air has moved farther than the transmitted component in the carbonic acid. The spherical wave front is transformed into an hyperboloid on entering the denser medium. This is well shown in No. 3 of the series. In No. 4 the wave is seen in air, having been reflected up from the bottom of the tank.

In fig. 10, Pl. III, we have the refraction of the wave in the same tank under oblique incidence. The bending of the wave within the tank is very marked. The wave fronts reflected from the side which follows the unreflected portion is also interesting in connection with Lloyd's single mirror interference experiment (No. 2 of series).

After several failures I succeeded in constructing a prism with its two refracting faces of this exceedingly thin collodion, which, when filled with carbonic acid, showed the bending of the wave front exactly as we figure it in diagrams for light. It was necessary to have the collodion thinner than before, since if we are to photograph the wave after twice traversing the film, we must lose as little energy as possible by reflection. Fig. 11, Pl. III, shows the refraction in a carbonic-acid prism, the bending being particularly noticeable in No. 4, on which I have, with a pair of dividers, traced out the position which the wave front would have occupied had it not traversed the prism.

The bending of the wave front in the opposite direction is shown in fig. 12, Pl. III, where the same prism is filled with hydrogen gas, in which sound travels faster than in air.

In the next figure we have a very interesting case, though, owing to the experimental difficulties, the photographs are not quite as satisfactory as some of the others. It represents the transformation of a spherical into a plane wave by passage through a double convex lens.

The construction of the cylindrical lens of exceedingly thin collodion was a matter of great difficulty. The flat, circular ends were made of thin mica as free from striæ as possible, that the passage of the wave through the lens could be followed. On these disks the collodion film was wound, the whole forming a hollow drum, which was then filled with carbonic acid. The sound wave, started at the principal focus of this lens, is seen to be quite flat after its emergence (fig. 13, Pl. III).

We will next take up some cases of diffraction, beginning with the well-known principle of Huygens, that any small portion of a wave front can be considered as the center of a secondary disturbance and that a small portion of this secondary disturbance can act as a new center in its turn.

In fig. 14, Pl. III, we have the wave starting above a plate with a narrow slit in it. This slit is seen to be the center of a secondary hemicylindrical wave which moves down precisely as if the spark were located at the slit. After proceeding a short distance this secondary wave encounters a second slit, and the same thing happens as before, the little slice that gets through spreading out into a complete wave, while the intercepted portion bounces back and forth between the plates.

Fig. 15, Pl. IV, shows the very limited extent to which sound shadows are formed. The wave is intercepted by a small glass plate. Just below the plate in No. 3 of the series a gap in the wave is found, which constitutes a shadow. But presently, by diffraction, the wave curls in, closing up the gap and obliterating the shadow entirely. In the last one of the series it is interesting to note how the diffracted waves have their centers at the edges of the obstacle, the edges acting as secondary sources, as in the case of the diffraction of light.

The passage of a wave through a diffraction grating is shown in fig. 16, Pl. IV. The grating is made of strips of glass arranged on a cylindrical surface, the wave starting at the center of curvature. In No. 2 of the series the union of the secondary disturbances coming from the openings into a new wave front is beautifully shown. In No. 3 the reflected wavelets have converged to the center, but as each one is a complete hemicylinder, we see them radiating from the center. This form can be constructed by describing semicircles around points on a circle of such radius that they all pass through the circle's center. These semicircles represent secondary wavelets starting simultaneously from the various grating elements. In the last three pictures of the series the wave passes down, strikes the table, and is reflected up again, and it is interesting to see how the medium is broken up into meshes by the crossing and recrossing of the secondary waves.

Fig. 17, Pl. IV, shows the form of the secondary wavelets formed by the reflection of a wave from a corrugated surface and is interesting in connection with reflection gratings.

The formation of a musical note by the reflection of a single pulse from a flight of steps is shown photographed in fig. 18, Pl. IV. This phenomenon is often noticed on a still night when walking on a stone pavement alongside a picket fence, the sound of each footstep being reflected from the palings as a metallic squeak, which Young has pointed out to be analogous to the power of a diffraction grating to construct light of a definite wave length.

It occurred to me, while making some geometrical constructions to aid in unraveling some of the complicated forms reflected from surfaces of circular curvature, that a very vivid idea of how these curious wave fronts are derived one from another could be obtained if a complete series could be prepared on the film of a cinematograph, and projected in motion on a screen.

Having been unable to so control the time interval between the two sparks that a progressive series could be taken, I adopted the simpler method of making a large number of geometrical constructions and then photographing them on a cinematograph film.

As a very large number of drawings (one hundred or so) must be made if the result is to be at all satisfactory, a method is desirable that will reduce the labor to a minimum. I may be permitted to give, as an instance, the method that I devised for building the series illustrating the reflection of a plane wave in a spherical mirror. The construction is shown in fig. 19.

ABC is the mirror, AOC the plane wave. Around points on ABC as centers describe circles tangent to the wave. These circles will be enveloped by another surface, ADE, below the mirror (the orthogonal surface). If we erect normals on this surface, we have the reflected rays; and if we measure off equal distances on the normals, we have the reflected wave front. By drawing the orthogonal surface we avoid the complication of having to measure off the distances around a corner. The orthogonal surface is an epicycloid formed by the rolling of a circle of a diameter equal to the radius of curvature of the mirror on the mirror's surface, and normals can be erected by drawing the arc FG (the path of the center of the generating circle) and describing circles of diameter BE around various points on it. A line joining the point of intersection of one of these circles with the epicycloid and the point of tangency with the mirror will, when produced, give a reflected ray; for example, JK produced for circle described around H. The construction once prepared, the series of wave-front pictures can be very quickly made. Three or four sheets of paper are laid under the construction, and holes are punched through the pile by means of a pin, at equal distances along each ray (measured from the orthogonal surface).

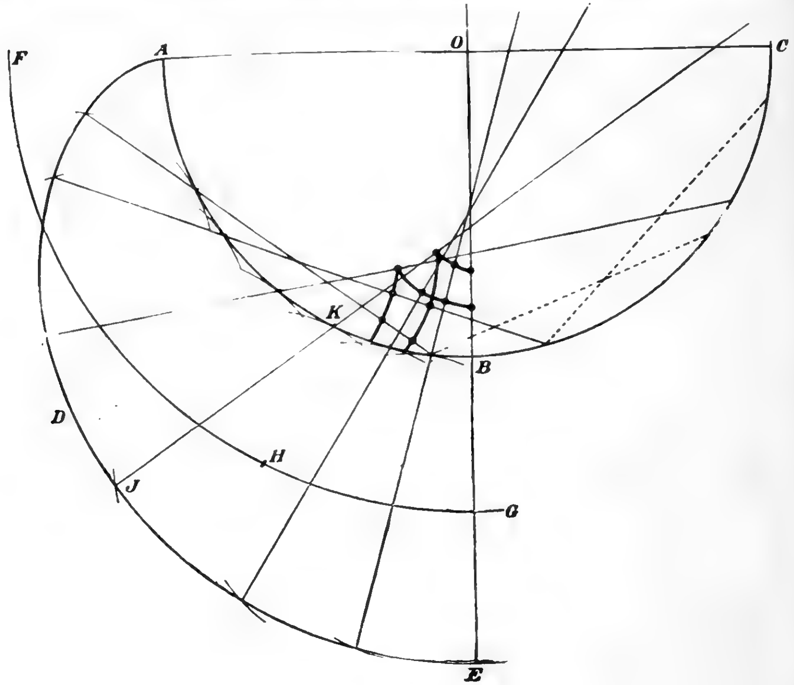

FIG. 19.

The center of the mirror and the point where its axis meets the surface are also indicated in the same manner. The sheets are now separated, and corresponding pin holes are united on each sheet by a broad black line, which represents the wave front. After a time it becomes necessary to consider double reflections, and to do this we are compelled to construct twice-reflected rays (indicated by dotted lines), and measure around a corner each time.

About a hundred pictures are prepared for each series, and the pictures then photographed separately on the film, which, when run through the animatograph, give a very vivid representation of the motion of the wave front.

Three films have been prepared thus far—reflection of a wave entering a concave hemispherical mirror (fig. 20, Pl. V); reflection of a spherical wave starting in the principal focus of a concave hemispherical mirror (fig. 21, Pl. V), and the reflection of a similar wave within a complete spherical mirror (fig. 22, Pl. VI). A number of these constructions, taken at intervals along the film, are reproduced, and comparison of them with the actual photographs shows the close agreement between the calculated forms and those actually obtained.

I have already mentioned the fact that the cusps on the wave fronts trace out the caustic surfaces. This is beautifully shown in figs. 23 and 24, Pl. VI, where the successive fronts are seen superposed. The former is for the reflection of a plane wave in a spherical mirror, the latter for the reflection of a spherical wave starting at the focus of a similar mirror. The caustic curve is shown by a dotted line in fig. 23, and is seen to be traced by the cusps on the wave fronts. The construction shows that there is a concentration of energy at the cusp; consequently we may define the cusp as a moving focus, and the caustic as the surface traced by it. Though I hesitate in claiming that this relation, at once so apparent, is at all novel, I may say that, so far as I have been able to find, it is not brought out in any of the text-books, caustic surfaces being invariably treated by ray rather than by wave-front methods.

The cinematograph series illustrating reflection inside a complete sphere was the most difficult to prepare, as several reflections had to be considered. It has been completed for three reflections, and Mr. Max Mason, of Madison, to whom I am greatly indebted for his patient work in assisting me, is going on with the series. As will be seen, the wave has already become quite complicated, and it will be interesting to see what further changes result after three or four more reflections. I am also under obligations to Prof. A. B. Porter, of Chicago, who prepared the set of drawings illustrating the passage of a wave out from the principal focus of a hemispherical mirror.

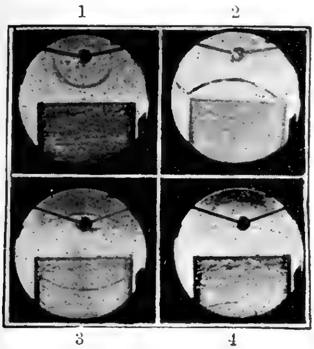

Fig. 9.

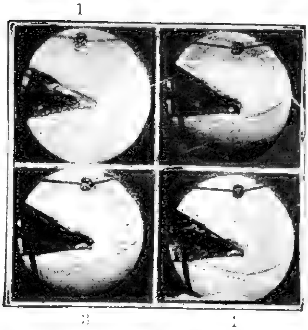

Fig. 11.

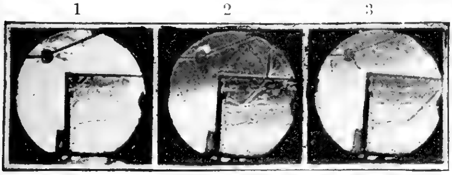

Fig. 10.

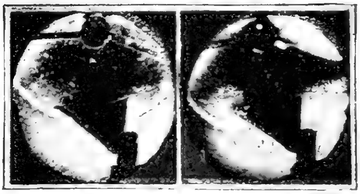

Fig. 12.

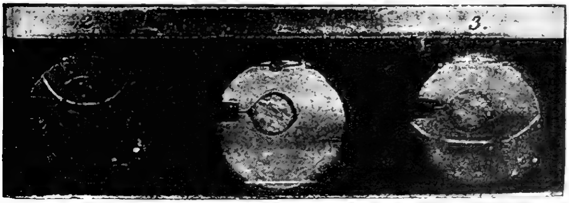

Fig. 13.

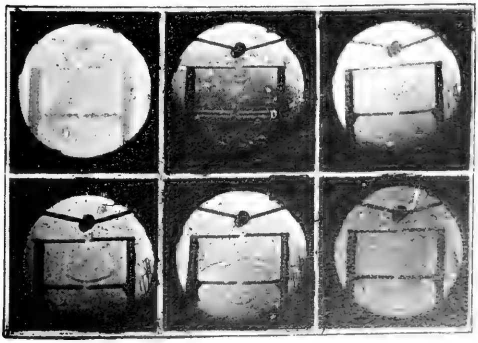

Fig. 14.

PHOTOGRAPHY OF SOUND WAVES

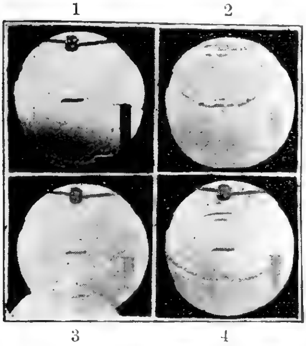

Fig. 15.

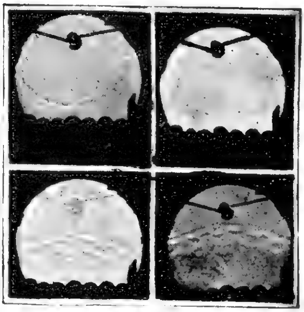

Fig. 17.

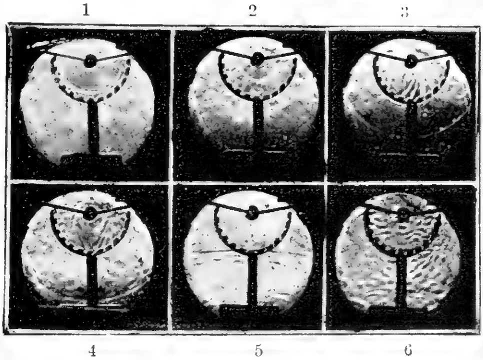

Fig. 16.

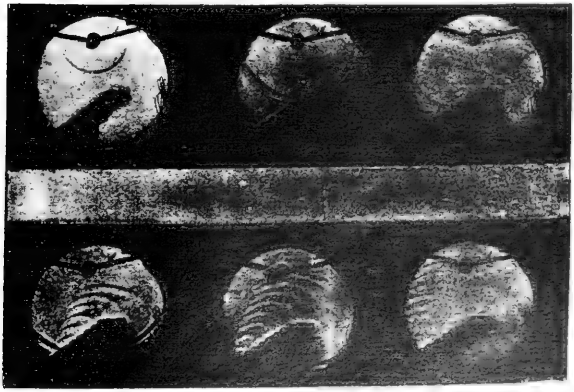

Fig. 18.

PHOTOGRAPHY OF SOUND WAVES.

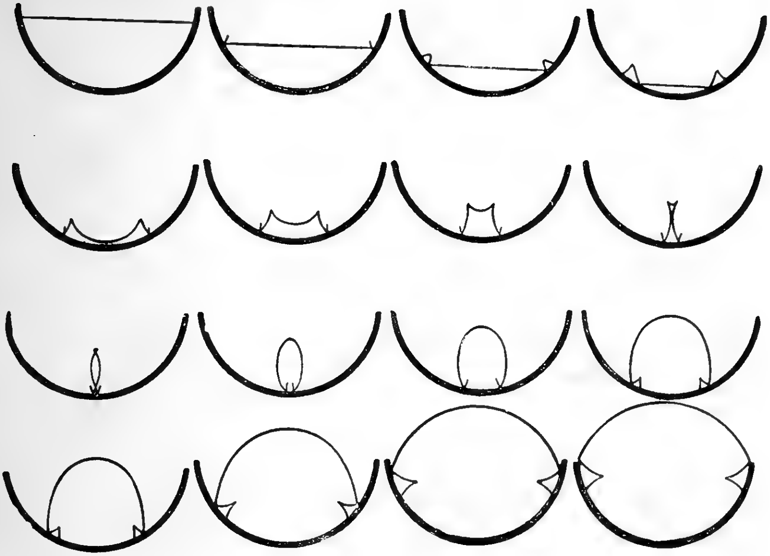

Fig. 20.

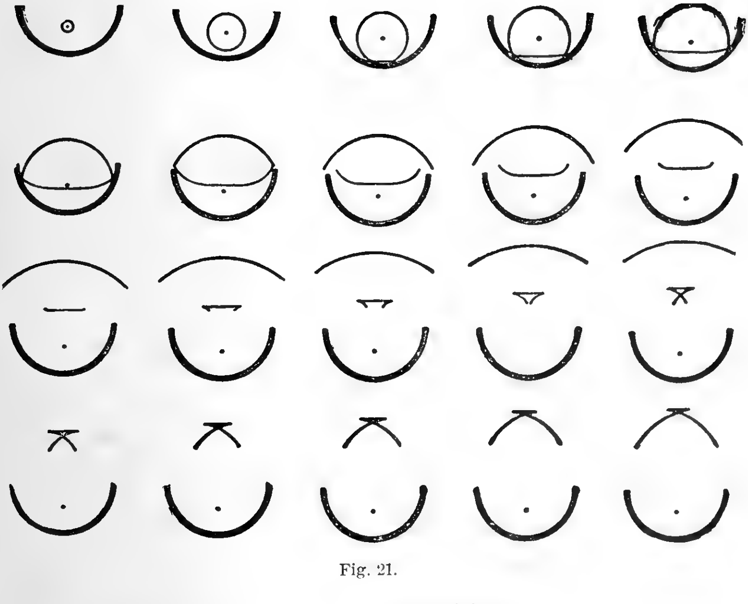

Fig. 21.

PHOTOGRAPHY OF SOUND WAVES.

Fig. 23.

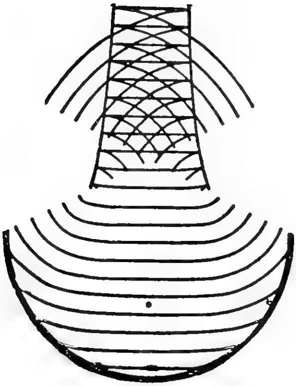

Fig. 24.

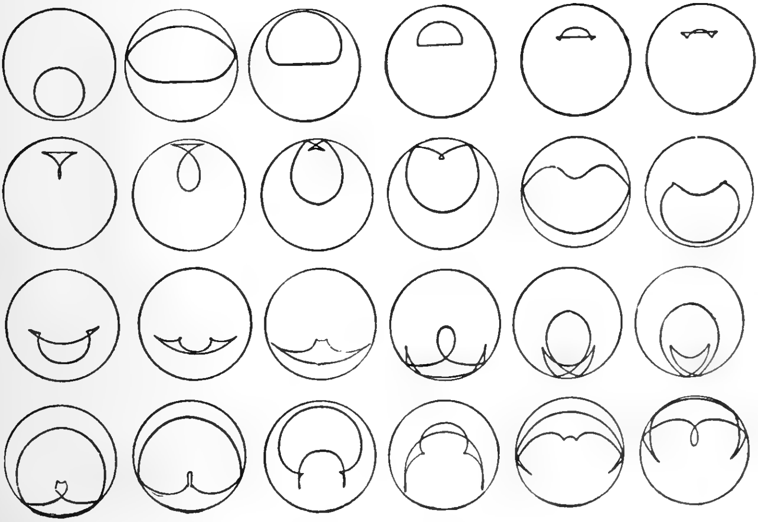

Fig. 22.

PHOTOGRAPHY OF SOUND WAVES.

UNSUSPECTED RADIATIONS.[1]

By Prince Kropotkin.

The sensation created five years ago by the discovery of the Röntgen rays had hardly begun to subside, and the patient, minute exploration of the newly opened field was only just beginning, when new, and new discoveries of formerly unsuspected radiations, came to add to the already great complexity of the phenomena, upsetting the provisional generalizations, raising new problems, and preparing the mind for further discoveries of a still more puzzling character. At the present time the physicist has to account for not only the kathode and the X or Röntgen rays, but also for the "secondary" or "S-rays" of Sagnac, the "Goldstein rays," the "Becquerel rays," and, in fact, for all the radiations belonging to the immense border land between electricity and light. Nay, most fundamental questions concerning the intimate structure of matter are being raised in connection with these investigations, and the physicist can not elude them any longer, because one of his most important principles, established by Carnot and generally recognized since, seems also to require revision, or has, at least, to receive a new interpretation.

So many different "rays" are now under consideration that it is necessary to begin by well defining them in a few words, even at the risk of repeating things already said in these pages and generally known. The "vacuum tube" is the starting point for all new radiations, and in its simplest form it is, as is known, a sealed glass tube, out of which the air has been pumped, and which has at each end a piece of platinum wire passed through the glass and entering the tube. When these two wires are connected with the two poles of an induction coil, or the electrodes of an influence electrical machine, or a powerful battery, they become poles themselves. The tube begins to glow with a beautiful light, and a stream of luminous matter flows from its negative pole—the kathode—to the positive pole. These are the kathode rays, the detailed exploration of which was begun years ago by Hittorf, but won a special interest when Crookes took them in hand, and once more when the

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[1] Reprinted from The Nineteenth Century, No. 286, December, 1900, by permission of Leonard Scott Publication Company.

Hungarian professor, Lenard, began to study them, in the years 1893–1895. It is evident that the glass tube may be given any shape that is found convenient for some special purpose, and that the degree of exhaustion of air (or of any other gas with which the vessel was filled before exhaustion), the forms and the disposition of the two poles, as also all other details of construction, may be varied at will, according to the experiments which are intended to be made. Now, if such a tube be placed inside a black cardboard muff which intercepts its light, and if it be brought into a dark room near to a screen painted with some phosphorescent substance, this substance begins to glow, although no visible light is falling upon it. If a wire be placed between the tube and the screen, its shadow appears on the screen, and if the hand be placed instead of the wire, dark shadows of the bones, but almost none of the flesh, are projected. A thick book gives, however, no shadow at all; it is transparent for these rays. Some radiations, proceeding along straight lines, must consequently issue from the tube and pass through the cardboard muff. Like light, they make the phosphorescent screen glow, move in straight lines (as they give shadows), and decompose the salts of the photographic film; but they are invisible and pass through such bodies as are opaque for ordinary light. These are the X or Röntgen rays.

Various secondary rays originate from them. If the Röntgen rays meet a metallic mirror, they are not reflected by it, but simply diffused—that is, thrown irregularly in all directions; and, although they do not pass through metals as a rule, they may be made strong and penetrating enough to pass through thin metallic plates. But in both cases they will acquire some new properties which will depend upon the metal which has diffused them or through which they have passed. Some new radiations will be added to them, and these radiations were named secondary rays, or S rays, by M. Sagnac, who discovered them. On the other hand, if kathode rays have been passed through a perforated metallic plate, they also get altered, and in this case they will sometimes be named Goldstein rays. And, finally, there is a very wide set of extremely interesting (also invisible) radiations emitted by phosphorescent substances. They were discovered by H. Becquerel, and are named now Becquerel rays or uranium rays. More will be said of them presently.

This is, then, the world of radiations the very existence of which was mostly unsuspected five years ago, and which have to be explained—the difficulty being in that they link together the Hertzian waves which are now used for wireless telegraphy, the visible light, the invisible radiations in the ultra-red and the ultra-violet parts of the spectrum, to so-called "actinic" glow of various substances placed in the violet portion of the spectrum, and many other phenomena. Light, electricity, magnetism, and the molecular movements of gases, liquids, and solids—all these formerly separated chapters of physics have thus been brought into a most intimate connection and huddled together by these wonderful radiations.

Thousands of most delicate experiments have been made and hundreds of papers have been written during the last five years, in order to determine the properties and the constitution of these different sorts of rays. Various hypotheses have been advocated, and yet scientific opinion is still hesitating, the more so as new discoveries are made all the time, and they show that we are not yet the masters of the whole series of phenomena brought under our notice. Upon one point only—and a very important one—a certain consensus of opinion begins to be established; namely, as to the kathode rays. Most explorers, including Lenard,[1] begin to be won to the idea that the kathode rays are the paths of very minute particles of matter which are thrown at a very great speed from the surface of the kathode and are loaded with electricity. Even under ordinary conditions, when an electric discharge takes place between one metallic electrode and the other under the ordinary atmospheric pressure in a room we see that most minute particles of the metal are torn off the negative electrode (the kathode) and are transported in the electric spark. Molecules of air join in the stream, creating the well-known "electric wind," and the air path of the electric spark becomes electrified to some extent. The more so when the discharge takes place in the extremely rarefied medium of a vacuum tube.[2] In this case the molecules of the rarefied gas, as also the metallic particles joining the current, are transported at a much greater speed, and we see them as a cone of light.

That kathode rays are real streams of particles of matter seemed very probable already in 1896, when the subject was discussed in these pages.[3] Recent researches tend to confirm more and more this idea. They act as a real molecular or atomic bombardment and they heat the objects they fall upon; thus, a thin lamella of glass which is placed in their path will be molten.[4] It is also known from Crookes's experiments that when a little mill is placed so as to receive them on its wings it is set in motion, and a back current seems to be originated at the same time, as has been demonstrated by Swinton.[5] They are deflected from their straight path by a magnet and are twisted along the lines

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[1] Annalen der Physik, 1898, Vol. LXIV, p. 279.

[2] I chiefly follow here Prof. J. J. Thomson, who has explained his views in several articles (Philosophical Magazine, October, 1897, Vol. XLIV, 5th series, p. 293; 1898; Vol. XLVI, p. 528; 1899, Vol. XLVIII, p. 547; also Nature, 1898, Vol. LVIII, p. 8, 1900, Vol. LXII, p. 31); and also Dr. L. Zehnder, the author of a Mechanik des Weltalls (1897), in his address before the Freiburg Natural History Society in 1898.

[3] Recent Science, in Nineteenth Century, March, 1896.

[4] Goldstein's researches into the compound nature of the cathode rays and their effects deserve a special notice. They are published in several issues of the Annalen der Physik for the last few years.

[5] Swinton in Philosophical Magazine, 1898, Vol. XLVI, p. 387; Broca, Comptes Rendus, 1899, Vol. CXXVIII, p. 356.

of force. Besides, a weak electrostatic force has upon them the same effect, showing that they are electrified negatively. Perrin[1] and others who followed him have proved that these rays carry negative electricity with them. If they are taken out of the vacuum tube in which they originated to another tube and are made there to fall upon an electroscope they discharge it. Negative electricity can not be separated from them: it follows with them when they are deflected by a magnet; it is their property—not something added to them.

Moreover, it was already noticed by Crookes, and confirmed since by Professor Thomson, that most of their properties do not depend upon the nature of the gas—air, oxygen, hydrogen, etc.—with which the tube was filled first, and of which a minute quantity always remains in the tube. They appear as a property of matter altogether rather than a property of this or that gas. And when attempts were lately made to measure the sizes of the particles which are carried in the kathode rays, it was found that they are extremely minute—much smaller than the probable size of atoms—while the charges of electricity which they carry with them are relatively great.[2]

All these facts have brought Prof. J. J. Thomson to the conclusion that the matter which is carried in the cathode rays is not ordinary matter, such as we know it in our everyday chemical experience, but matter in a state of a high dissociation. We know that the molecules of all bodies in nature consist of atoms; but even these atoms, small though they must be, are giants in comparison with the particles transported in the kathode streams. Consequently, we must think that the atoms themselves are dissociated in the intensive electric field. They divide into what we may call the primary atoms of some primary matter out of which the atoms of all chemical elements must be built up, and these primary atoms are carriers of electricity.[3] Of course, not every molecule need be dissociated, and some experiments show that the number of dissociated molecules is really very small in comparison with their total number. If one out of each three milliards of molecules is in a state of dissociation, this will do to account for the facts and the measurements which have been made, although many more molecules may have been dissociated in the kathode stream only to be reconstructed after having exchanged atoms with their neighbors.

It must be said in favor of this hypothesis that dissociation under the action of violent electrical vibrations—i. e., the breaking up of molecules into *ions*, or elementary atoms carrying electricity with them—is familiar to physicists. Besides, if we can not yet specify what we

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[1] Annalen der Physik, 1898, Vol. LXVI, p. 1.

[2] J. J. Thomson, Philosophical Magazine, Vol. XLVI, p. 528.

[3] Professor Thomson names them "corpuscles," but this is hardly an appropriate name for such minute subdivisions of the atoms. To the biologist it conveys an idea of organization; and in physics it was used formerly as a substitute for "molecules."

mean by our atoms "carrying negative or positive electricity," we may imagine that this means carrying a certain vibratory or, perhaps, spiral movement, or any other sort of motion which we prefer not to specify in order to avoid spreading conceptions which may prove to be erroneous. But we know for certain that gases, which usually are no conductors of electricity, become conductors under the influence of electric discharges, as also of the ultraviolet light, or even after having passed through flames. In such cases they become able to transport electricity—that is, some motion or some state unknown, which we name electricity—from one spot of space to another. A stream of dissociated and electrified particles of matter rushing in the kathode stream is thus a very probable explanation—the more so as similar streams are already admitted in order to explain the electro-chemical decomposition of salts and many properties of solutions.[1] The kathode rays would then be "an electric dance of atoms along the lines of force," as Villari and Righi have expressed it.

One question only must be asked: Is it necessary to suppose that the molecules are so dissociated as to set free the "primary matter" out of which the atoms of all elements are composed? Theoretically, there is no objection to this view. Modern science knows that the atoms—or the "chemical individuals," as Mendeléeff would prefer to name them—are only treated as indivisible in the chemical processes in the same sense as molecules are (or rather were) treated as indivisible in physical processes. The modern physicist does not consider the atoms indivisible in the sense Democritus taught it, but in the sense in which the sun is an individual amid the boundless interstellar space. He is even inclined to admit that the atoms have a complicated structure and are vortex rings similar to rings of smoke (Lord Kelvin and Helmholtz), or minute systems similar to planetary systems (Mendeléeff).[2] The "dissociation of atoms" would therefore be admissible; but before admitting the ultimate dissociation advocated by J. J. Thomson, can we not find a simpler explanation? Several explorers are inclined to think so, and Dr. Villard points out one possible issue. The kathode rays are, in his opinion, mere streams of hydrogen atoms or molecules—the presence of this gas in all tubes, even the best exhausted, being explained by the particles of water sticking to the glass, or by the decomposition of the alkalies of the glass. One fact certainly speaks in favor of Villard's view: A small copper oxide plate, being so placed as to receive the kathode rays, parts with its oxygen (is reduced) just as if it had been struck by a jet of hot hydrogen. Besides, the spots where the rays fall upon the glass of the tube are blackened, and these

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[1] See Recent Science, in Nineteenth Century, August, 1892, and January, 1894.

[2] Let me mention in connection with this a brilliant article by Mendeléeff on "Matter," in the new Russian Encyclopedic Dictionary, published by Brockhaus & Efron, Vol. VI, p. 151.

black spots again are such as if they had undergone a hydrogen bombardment. Moreover, the spectroscope reveals the hydrogen line in the glowing tubes.[1] But all this, while proving the presence of hydrogen in the vacuum tubes, does not speak against the hypothesis of J. J. Thomson, which still remains, up till now, the most plausible explanation of the kathode rays.

And yet one feels that the last word even about these rays has not yet been said. Dr. Joseph Larmor was quite right when he remarked, in his suggestive address delivered before the British association at Bradford,[2] that the study of electrical discharge in rarefied gases has conduced us to enlarged knowledge "of the fundamental relations in which the individual molecules stand to all electrical phenomena." Up till now we took these phenomena in a block. We studied the sum total of the actions of an infinity of molecules in a certain direction. Now we are bound to question the molecule itself as to its speed, its behavior, and its constitutive parts, and we find that a mobility of its component parts must be taken into account instead of the rigidity with which we formerly endowed it.

The philosophical value of this new move in electrodynamics—the value of the principle of action being introduced into the theories of vibration of the formerly "immaterial" ether—is immense, and it is sure to bear fruit in natural philosophy altogether. Ether itself, after having resisted so long all attempts to seize its true characters, becomes dissociated matter, filling space and upsetting many an old preconceived idea. No wonder, then, if it takes us some time before our views are settled upon these new phenomena, so full of unexpected revelations and philosophical consequences.

If the kathode rays are in all probability streams of dissociated molecules which are thrown off the kathode, what are, then, the Röntgen or X-rays? They certainly originate from the former, either in the spot where they strike the glass or, what appears more correct, within the tube itself in the kathode stream. But are both of the same nature? Röntgen himself indicates many points of resemblance between the two, and considers them in his third memoir[3] as "phenomena probably of the same nature." Lenard goes even a step further. He represents them both as parts of the same scale or of the same "magnetic spectrum;" the X-rays, which are not deflected by a magnet, being at one end of the scale, while a series of intermediate radiations connect them with the kathode rays occupying the other end of the scale.[4] Both provoke fluorescence, both produce similar photographic and

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[1] Dr. P. Villard, in Revue Générale des Sciences, 1899, Vol. X, p. 101.

[2] Nature, the 6th of October, 1900, Vol. LXII, p. 449, gives it in full.

[3] Sitzungsberichte of the Berlin Academy of Sciences, 1897, p. 576; summed up in various scientific reviews.

[4] Annalen der Physik, 1897, Vol. LXIII, p. 253.

electric effects, and both have different degrees of penetration through opaque bodies, which depend upon the source of electricity and the media through which they have passed. Moreover, the X-rays are certainly not homogeneous, and consist of a variety of radiations.

And yet the many analogies which have been noticed between the Röntgen rays and ordinary light stand in opposition to a full assimilation of the X-rays to the kathode streams, and the opinion that, like light, they are vibrations of the ether takes the upper hand.[1] These may be vibrations of a very short wave length, perhaps a hundred times shorter than the waves of green light; or they may be "longitudinal vibrations," as Lord Kelvin had suggested at the outset;[2] or, as Prof. J. J. Thomson thinks, they may be a mixture of vibrations of different sorts—"pulsations" of the ether, as he puts it—that is, something similar to what is called "a noise" in the theory of sound.

Already, in his second memoir, Röntgen had indicated that his rays discharge an electrified body, both directly when they fall upon it and by their action upon the surrounding air, which they render a conductor of electricity. This was an important remark, because the researches of the previous four years had firmly established that the violet rays—i. e., the short waves of light—as well as the invisible ultraviolet radiations, have the very same effect. A link was thus established between the problematic rays and common light, and some of the best physicists (Lord Kelvin, Righi, Perrin, Guggenheimer, Villari, Starke, and many others) engaged in a minute experimental work in order to specify these analogies. The result was that the resemblance between the X-rays and the short-waved radiations of light was proved.

A further confirmation of the same analogy was given by the discovery of the "secondary" and "tertiary" rays by the Paris professor, G. Sagnac.[3] He studied what becomes of the Röntgen rays when they strike different metallic surfaces. They are not reflected by them, but only diffused irregularly; however, this diffusion differs from reflection, not only by its irregularity, but still more by the fact that the character of the "secondary" radiations (or "tertiary," if they have been diffused twice) is altered. They become more like ordinary light.

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[1] See Geitler's objections against such an assimilation, based upon their different behavior toward electrified bodies (Annalen der Physik, Vol. LXVI, p. 65), to which it may be added that the heating effect of the first radiations is very much smaller than the same effect of the latter (E. Dorn), and compare these remarks with the anode current, the existence of which was maintained by Crookes since 1891. Swinton (Phil. Mag., 1898, XLVI, p. 387) confirmed its existence, and Riecke (Ann. der Physik, XLVI, p. 954) has measured its energy.

[2] See Nineteenth Century, March, 1896, where the meaning of this suggestion was explained.

[3] He gave an account of his researches in Revue Générale des Sciences, the 30th of April, 1898.

Their power of penetration through opaque wood or the human flesh is diminished; and just as a phosphorescing surface which has been struck by ultraviolet radiations begins to glow with a yellow or green light—of a diminished wave length, as G. G. Stokes had remarked it—so also the diffused secondary radiations behave as if they were of shorter wave lengths than the rays which originated them. The space between the violet light and the Röntgen radiations is thus bridged over, their analogy with light becomes closer, and the hypothesis according to which they are treated as vibrations of the ether gains further support.

Many other curious properties of the Röntgen rays have been revealed during the last four years. The most interesting is that they are not quite "invisible light." When they are of great intensity they become visible. However, the portions of our retina which are excited by them are the peripheral parts only, which contain more rods than the central parts lying opposite the iris. The cones, or those constituent parts of the retina which are supposed to convey to our brain the color sensations, are, on the contrary, but very slightly, if at all, irritated by the X-rays.[1] Then the more perfect is the vacuum in a Crookes tube, and consequently the greater is the electrical force required to originate Röntgen rays, the more penetrating they are. In such cases they pass through metals, and Röntgen himself has photographed bullets inside a double-barreled Lefaucheux pistol, while other explorers have obtained radiograms with rays which had passed through an aluminum plate 1.4 inches thick, and even a cast-iron plate nearly 1 inch thick.[2] The inside of a watch which had a steel lid, the inner mechanism of a lock, as also both sides of a bronze medal, were photographed in the same way; while, on the other hand, Goldstein obtained beautiful radiograms showing the internal structure of a Nymphæa flower, of a hermit crab inside its shell, and so on.[3]

But the chief progress was made with the medical applications of the Röntgen rays. The half-mystical enthusiasm of the first days, when they were supposed to provide a new curative method, rapidly subsided. But their usefulness for ascertaining lesions in the bones, and for the discovery of the actual position of strange bodies—bullets, needles, and so on—in the human tissues, has grown in proportion as surgeons have learned better to handle them.

The pernicious effects of the invisible rays on the skin are now eliminated by shortening the time of exposure which is required to obtain

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[1] Prof. Elihu Thomson's address delivered before the American Association of Science in 1899 (Science, 1899, Vol. X, p. 236; translated in Naturwissenschaftliche Rundschau, XIV, p. 585).

[2] Radiguet, Sagnac, Hall Edwards.

[3] Max Levy, "Fortschritte der Röntgentechnik," reproduced in various periodicals.

a good radiogram, and the morbid effects have been traced by Russian explorers (Danilevsky, Tarkhanoff) to electric radiations altogether, rather than to the X-rays themselves. Formerly it required eighteen minutes to obtain a radiogram of the hand. Now we are told that Dr. Donath obtains in two seconds a distinct radiogram of so difficult a subject as the shoulder and the chest; while Tesla, with his powerful alternate currents, could show distinct shadows at a distance of 165 feet from the vacuum tube. In the hands of an able surgeon—as Prof. E. Bergmann illustrated before the Association of German Naturalists and Physicians in 1899—the X-rays become a most precious means of exploration. The growth of the bones, from birth till matured age, could be studied with their aid, and the various causes which retard growth (rachitism, tuberculosis) or produce midgets could be ascertained. The fearful splintering of the bones by the modern bullets, and especially by the English dumdum bullet, became known, and the radiograms of Bruns showing the effects of the dumdum provoked on the Continent a unanimous indignation against this bullet. Many limbs were saved during the last Greek-Turkish war by Nasse and Küttner continually resorting to radiography. So also in the Soudan war. In fractures of the kneecap the Röntgen rays have proved simply invaluable, but perhaps the best service they rendered was to demonstrate that in many cases it was far preferable to leave pellets of lead, small revolver bullets, and even Peabody-Martini bullets where they were lodged in the tissues instead of trying to get them out. In fact, Dr. Bergmann's radiograms prove that a bullet may sometimes remain in the lungs without occasioning any trouble. Such was the case of a German soldier who had carried a bullet in his lungs for twenty-nine years, since 1871, without knowing it. The German professor goes even so far as to maintain that there are cases when a small bullet lodged in the white mass of the brain will remain there firmly imbedded, without producing any noticeable trouble, and that there is less danger in leaving it there than in extracting it.

If Röntgen's discovery had only the effect of alleviating so many human miseries, it would already rank among the great achievements of the century, but its profound effects upon natural philosophy are far from being yet exhausted.

Every one knows the phosphorescent match boxes provided with a white surface, which is usually protected from moisture by a glass, and glows in the darkness, making the box visible at night. Sulphide of lime is generally used for making such glowing surfaces, but various compounds of barium, calcium, strontium, uranium, and so on possess the same property of glowing in the dark after they have been exposed for some time to light. They are said in this case to "store up" light energy, which they give away afterwards; this was, at least, the explanation that used to be given some time ago.[1] Now, it was in this rather neglected domain that Henri Becquerel discovered the wonderful radiations which have received his name, and which, owing to the speculations they provoked as regards the theory of matter, have engrossed for the last four years the attention of physicists, even more than the Röntgen rays themselves.

It will be remembered that a phosphorescent screen which began to glow in the proximity of a vacuum tube upon which Röntgen was experimenting led him to his memorable discovery. It was only natural, therefore, to see whether phosphorescent screens would not reinforce the X-rays; and in the course of such experiments M. Henry noticed that a phosphorescent sulphide of zinc gave up radiations which, like the Röntgen rays, would pass through black paper and affect after that the photographic plate.[2] M. Niewenglowski, also at Paris, made the same remark concerning a sulphide of lime previously exposed to light.[3] Then, at the next sitting of the Paris Academy of Sciences Henri Becquerel came forward with a work on the radiations emitted by phosphorescent substances,[4] and this first work was followed by quite a number of papers in which the new radiations were studied under all possible aspects. Becquerel was joined in his researches by many others, and especially by Mme. Sklodowska-Curie and her husband, M. Pierre Curie, who soon discovered, with the aid of the new radiations, two new elements, and by this time the "Becquerel rays" have already a bulky literature. During the past year nearly every week brought with it the discovery of some new and puzzling property of these radiations.[5]

The main point of the discovery was that phosphorescent bodies emit not only the well-known glow, which is visible to our eye, but also invisible radiations, similar to the Röntgen ray. Some salts of the metal uranium, and the metal itself, need not be exposed to light

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[1] The terms "phosphorescence" and "fluorescence" are rather indiscriminately used to describe glowing after an exposure to light, as the distinction between the two, proposed by Wiedemann, can not be maintained any longer. Other causes may also provoke "luminescence:" the diamond glows after having been slightly heated, quartz after some rubbing, and gases when they are electrified. As to the many luminescent animals, such as the glowworm, various marine animals and bacteria, we are not concerned with them now.

[2] Comptes Rendus of the Paris Academy of Sciences, the 10th of February, 1896, Vol. CXXII, p. 312.

[3] Ibid., CXXII, p. 386.

[4] Ibid., the 24th of February, 1896, Vol. CXXII, p. 420. Further communications in the same and subsequent volumes.

[5] The literature of the subject is already immense. The main contributions to it will be found in Comptes Rendus, Philosophical Magazine, and Annalen der Physik. Excellent articles for the general reader appeared in Nature, the 14th of June, 1900, and in Revue Générale des Sciences, the 30th of January, 1899, by Mme. Sklodowska-Curie.

for more than one-hundredth part of a second to begin to glow, and long after the glow has disappeared they continue to send out the invisible radiations affecting the photographic film for months, and even years, as it appeared later on, even though the salt of the metal remained all the time in a closed box locked in a drawer in a dark room. The Becquerel radiations are thus quite different from phosphorescence or fluorescence. They are similar in nature to the kathode rays and the Röntgen rays, with one substantial difference only. In the vacuum tube we know the force—electricity —which supplies the energy for setting the atoms or the molecules of the gas into motion, while here we see no such source of energy; the radiations continue months and years after the phosphorescent body has seen the light, and there is no notable diminution of its radiating activity. Besides, certain substances need not be influenced by light at all for sending out radiations, and this properly belongs, as it appeared later on, not only to phosphorescent bodies, but to a great variety of substances, organic and inorganic, so that one has to ask oneself whether the Becquerel radiations are not a property of matter altogether.

The first experiments of Becquerel were these: A little lamina of the double sulphide of uranium and potassium, which has a great phosphorescing power, was placed upon a black paper envelope containing a photographic film. A glass plate, or a thin plate of aluminum or of copper, was introduced between the two, and the whole was either exposed to diffused daylight or closed in a black box and put in a drawer. In a short time in the first case—in a few hours in the second—the photographic film would show that some rays had been radiated from the sulphide. They had traversed the paper and partly also the metals, though less so than the paper, and the plate bore the image or the shadow of the piece of copper.

The analogy with the Röntgen rays was thus evident, and further inquiry confirmed it. Like the kathode rays, the Becquerel radiations are deflected from their rectilinear paths by a magnet; but, like the Röntgen rays, they can not be reflected or broken or polarized.[1] And, like the kathode rays, they render the air through which they pass a conductor of electricity; they carry electricity with them, and consequently it is most probable that they are not vibrations of the ether, but electrified particles of matter, or ions, like the kathode rays. And so we have the puzzle, or, at least, the quite unexpected fact, of matter radiating molecules without any electrical or luminous or heating cause provoking and maintaining that radiation or evaporation.

The Becquerel rays, as was just said, send electrified particles which are capable of neutralizing the electricity of other bodies with

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[1] In his first researches Becquerel thought that he had seen reflection and refraction of these rays; but now he has abandoned this idea (Comptes Rendus, 1899, Vol. CXXVIII, p. 771).

which they come into contact. The gold leaflets of a charged electroscope drop at the contact with them.[1] But Becquerel was not satisfied with merely stating this fact; he immediately devised a very delicate instrument for measuring the activity of different rays given up by various bodies. Perhaps he did not realize that he was thus endowing science with a new method of analysis, which would lead, like spectrum analysis, to the discovery of new elements; but in the hands of M. Curie and Madame Sklodowska-Curie this method really led to the discovery of at least one element, radium, and perhaps two more—polonium and actinium.

From the very outset it became evident that compounds of uranium, and especially the metal itself, prepared in a pure state by Moissan, in his electric furnace, were possessed of the greatest radio-activity. Thorium, with its compounds, came next. As to the other elements, nearly all of which were examined by Mme. Sklodowska, they were all much inferior to these two. It was also noticed during these researches that, as a rule, the compounds were inferior to the pure metals themselves. One mineral, however, the Bohemian pitchblende, as also two others of less importance—all compounds of uranium—proved to be much more radio-active than pure uranium itself, and M. and Mme. Curie, suspecting that the pitchblende must contain some new substance more active than uranium, began a most painstaking laboratory work in order to isolate that special substance. They obtained at last a metal identical as to its chemical properties with bismuth, but far more radio-active, and they named it polonium, in honor of Madame Sklodowska's fatherland. Then, beginning once more, in company with G. Bémont, the whole research from the beginning, in order to hunt for another very radio-active substance of which they had suspected the existence, they obtained another metal similar to barium by its chemical properties, but still more radio-active, which they named radium.[2] And finally, A. Debierne has discovered lately, by the same method, a third element named actinium and chemically similar to titanium.[3] Mr. Crookes, while disagreeing with the Curies as regards their new elements, came also, after a long research, to some new element, or at least to some new variety of uranium, which he named "Ur X," and which in his opinion is neither polonium nor radium.[4] The new method of "radiation analysis" had thus completed its proofs.

Of course, so long as these new elements have not been separated

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[1] This fundamental property of the Becquerel rays was announced on the very same day by Becquerel at Paris (Comptes Rendus, 1897, Vol. CXXIV, p. 438), and by Lord Kelvin, J. C. Beattie, and Smoluchowski Smolan at Edinburgh, before the Edinburgh Royal Society (Nature, 1897, Vol. XLV, p. 447).

[2] Comptes Rendus, 1899, Vol. CXXVII, p. 1215.

[3] Ibid., 1900, Vol. CXXX, p. 906.

[4] Proceedings of the Royal Society, the 10th of May, 1900.

chemically from their nearest of kin—bismuth, barium, and titanium—their existence must still remain doubtful. But the spectrum of radium has already been examined by Demarçay[1] and by Dr. C. Runge under a very great dispersion; and the great German specialist in spectra found that radium really gives three distinct lines which belong to no other element.[2]

The radio-activity of these new metals is really striking. For polonium it is four hundred times, and for radium nine hundred times, greater than for metallic uranium. Radium illuminates a phosphorescent screen indefinitely, and its salts glow without requiring for that a preliminary excitement by light. F. Giesel, who, almost simultaneously with the Curies, obtained a substance that must be radium, saw the chloride and bromide of this substance, although chemically identical with the same compounds of barium, sending such strong rays that the shadow of a hand appeared on a phosphorescent screen at a distance of 18 inches and the rays pierced metallic plates four-tenths and eight-tenths of an inch thick. Salts containing an admixture of the new substance were so phosphorescent that one could read in their blue light. As to polonium, although a pure specimen of it was as phosphorescent as pure radium, its invisible rays had, however, a much smaller penetrating power; even cardboard would weaken them.[3]

The main interest of these researches is, however, in the problematic nature of the Becquerel radiations. Are they not a general property of matter, only varying in degree in different substances? This is the question which is now asked. Some thirty or thirty-five years ago it was mentioned in some scientific reviews that various objects—a printed page or a piece of metal—left their impressions on a white sheet of paper if the two had been kept for some time at a small distance from each other. These experiments, which seemed to prove the existence of some sort of radiation of matter, interested me then a great deal because they gave support to a very ingenious theory, developed by Séguin, concerning the existence of infinitely small particles of matter dashing in all directions through space and penetrating matter. With the aid of these particles Séguin endeavored to explain gravitation, heat, light, and electricity. Now W. J. Russell, continuing the experiments of Colson on zinc and other metals,[4] laid before the Royal Society in the autumn of 1897, and later on with more details, in a Bakerian lecture, experiments having very much the same purport. He found that certain metals (magnesium, cadmium, zinc, nickel, etc.) and certain

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[1] Revue Générale des Sciences, the 30th of September, 1900, gives a photograph of this spectrum.

[2] Annalen der Physik, 1900, 4th series, Vol. II, p. 742. Polonium gave no characteristic lines.

[3] Physikalische Zeitschrift, Vol. I, 1900, p. 16.

[4] Comptes Rendus, 1896, Vol. CXXIII, p. 49.

organic bodies (printing ink, varnishes) will act on a photographic plate by their "emanations," exactly as if the plate had been acted upon by light, the boiled oil of the printing ink and the turpentine in varnish being the active substances. Remarkably clear photographs of a printed page and a lithographic print were thus obtained without the aid of light. Many organic substances act in the same way, and a piece of old dry board gives its likeness simply after having been laid for some time over a photographic film, while a plate of polished zinc, separated from the film by a sheet of paper, will send its radiations through the paper and give a photographic reproduction of its watermarks.[1]

In what relation these "emanations" stand to the Becquerel rays can not yet be determined. But it becomes more and more certain that, like the kathode rays, the Becquerel radiations also consist of material particles projected from the radio-active bodies and carrying electricity with them. They may possibly be accompanied by vibrations of ether of the nature of light, but the fact of a real transport of particles of matter is rendered more and more apparent by the researches of Becquerel, the Curies, Elster and Geitel,[2] and Rutherford.[3] The "emanations" from thorium compounds are even affected by drafts in the room. But these emanations are neither dust nor vapors. They must be atoms, or ions, of the radiating body, and they communicate radio-activity, and, consequently, the power of discharging electricity to the surfaces of the bodies with which they come in contact. From glass that "acquired" activity may be washed away, while to other bodies it clings like a sprinkling of the "jack-frost" powder, and M. Curie is described in Nature as being unable for a time to make electrostatic experiments on account of this "acquired" radio-activity.[4] Moreover, the Becquerel radiations exercise a chemical action; they ozonify air, as they "ionize" it, and a glass bottle which contains salts of radium takes a violet color, thus showing that chemical processes are provoked by the radiations.[5]

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[1] Proceedings of the Royal Society, Vol. LXI, p. 424. Bakerian lecture, delivered on the 24th of March, 1898; Nature, the 28th of April, Vol. LVII, p. 607.

[2] Verhandlungen der deutschen physischen Gesellschaft, 1900, p. 5; summed up in Naturwissenschaftliche Rundschau, Vol. XV, p. 103.

[3] Philosophical Magazine, 1899, Vol. XLVII, p. 109; 1900, Vol. XLIX, pp. 1, 161.

[4] See E. Rutherford's paper in Philosophical Magazine, 1900, Vol. XLIX, p. 161; also Nature.

[5] A salt of uranium may be submitted to absolutely any chemical transformations, but when you return to the salt from which you started in your work, you find in it the very same electrical radio-activity which it had at the start. Impurities do not affect it. The radiation seems thus to belong to the molecule of uranium, and hardly to be influenced by external causes. (Sklodowska-Curie, in Revue Générale, 1899, X, p. 47.)

Many problems relative to the structure and life of matter have thus been raised by these researches. Various hypotheses are offered to explain them, and J. J. Thompson's hypothesis—a further development of his kathode-rays hypothesis—appears, after all, the most probable. The molecules of which all bodies are composed are not something rigid. They live; that is, an atom or a "corpuscle" is continually being detached from this or that molecule, and it wanders through the gas, the liquid, or even through the solid;[1] another atom (or corpuscle) may next take its place in the broken molecule; and so a continual exchange of matter takes place within the gaseous, liquid, or solid bodies, the wandering "corpuscles" always carrying with them the sort of motion which we call an electrical charge. Those atoms or corpuscles which escape from the surface of the body would give what we call now Becquerel rays, and it would not be a simple coincidence that those two elements which possess the greatest atomic weights, and consequently have the most complex molecules,[2] possess also the highest radio-activity. We know that in solutions the so-called unstable compounds play an immense part; they are continually broken up, losing part of their atoms, and are continually reconstituted as they take in new atoms. And we know that in living matter the most compound molecules—those of albumen—are those which are split up most easily, and that what we call life consists in a continual splitting up and rebuilding of these molecules. Are not the Becquerel radiations revealing to us that continual splitting and rebuilding of molecules which constitutes the life of both inorganic and organic matter? These are the grave questions which natural philosophers are brought to ask themselves, and which will certainly require many more patient researches.

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[1] Compare with Roberts-Austen's researches on the permeation of solid metals, mentioned in a previous "Recent Science" article.

[2] Thorium, 232.6; uranium, 239.6. Both belong to the twelfth and last series of Mendeléeff. The atomic weight of radium must be greater than 174. (Comptes Rendus, CXXXI, p. 382.)

INCANDESCENT MANTLES.[1]

By Vivian B. Lewes, F. I. C., F. C. S.

There is nothing more wearying to the practical man than to listen to the preachings of the scientist who imagines that the thoughts born within the four walls of his study are superior to the hard-earned experience of years of labor, and nothing is further from my intention than to impose this suffering upon you. There are, however, sides to many questions which can be made clear; details, the explanation of which can help, and innovations, the description of which will interest those employed in actual every-day work, and it is in this way that lectures can be made most valuable, while the more practical working experiences find their most fitting record in the discussion which every lecturer hopes to excite.

It was long before the incandescent mantle came to the help of the gas engineer in his fight against the threatened encroachments of the electric light that the name of Auer von Welsbach became known to the scientific world as one of the most promising students in the domain of the rare earths that the world-famous laboratories of Heidelberg and Vienna had produced.

Boiling a solution of some of these rare oxides, and using a ragged sheet of asbestus card to shield the beaker containing the solution of the salts from the fierce flame of the Bunsen burner, he noticed that a small quantity of liquid, having boiled over and having evaporated on the projecting fibers at the edge of the card, endowed them with the power of becoming brilliantly incandescent under the exciting heat of the nonluminous flame. Seizing the clew thus obtained, Welsbach set himself to solve the problem of how to utilize the manifestly high light emissivity of these bodies as a practical aid to artificial illumination, and the result of that quest has been to place the gas industry well beyond the reach of electrical competition for many years to come, and to insure fame and more substantial reward to the keen

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[1] Paper read before the Institution of Gas Engineers, on May 3, by Vivian B. Lewes, Professor of Chemistry, Royal Naval College, Greenwich, England. Printed in Progressive Age. Reprinted in Scientific American Supplement, Nos. 1230, 1231, July 29, August 5, 1899.

worker whose practical appreciation of the importance of his discovery resulted in one of the most phenomenal successes of modern times.

The term "rare earths" is one of those anomalies which mar the vaunted precision of science, as although it might justly be applied to the oxides of many metals, it was in 1885 used to designate a small band of metallic oxides which occur in certain rare minerals, of which cerite and gadolinite may be taken as types.

The term "earth" was applied to such bodies as the oxide of chromium, Cr_2O_3; and alumina, Al_2O_3, while the "alkaline earths" were the calcium and magnesium groups.

These rare earths were generally considered to be: Cerium oxide, Ce_2O_3; lanthanum oxide, La_2O_3; didymium oxide, Dy_2O_3; yttrium oxide, Y_2O_3; erbium oxide, Er_2O_3; together with some others even scarcer, and these are divided into two groups:

Cerite earths.	Ytterite earths.
Cerium oxide,	Yttrium oxide,
Lanthanum oxide,	Erbium oxide,
Didymium oxide,	

which are easily divided from each other by the action of an excess of potassic sulphate, the cerite earths forming "alums" which are insoluble in potassic sulphate and so separate out, while the ytterite earths remain in solution. These rare earths are all bases, but there are other metallic oxides, equally rare, which play an important part in mantle making, but can not be classified with them. Thoria, ThO_2, and zirconia, ZrO_2, are not earths, and in some combinations show rather an acidulous than a basic tendency. These two metals, thorium and zirconium, are classed with titanium, silicon, etc.

It was with the study of these oxides that Welsbach was most concerned at the period when his early attempts began to assume tangible shape, and having discovered the possibility of making a mantle to fit the shape of a nonluminous Bunsen flame by soaking a cotton fabric in a solution of salts of the rare earths and then burning out the organic matter in such a way as to leave a ghost of the departed threads built up of the oxides of the metals used—thin enough to be excited to luminosity by the heat of the flame, and yet resistant enough to retain its shape under the temperature to which it was submitted—he took out his celebrated patent of 1885, which has proved an efficient first line of defense against those who, left without the charmed circle, yet have hungered for the baked meats within.

In the 1885 patent Welsbach protects the idea of making a mantle by saturating the cotton fabric and then burning off, using mixtures of the salts which he gives as "60 per cent zirconia or oxide of zirconium, 20 per cent oxide of lanthanum, 20 per cent oxide of yttrium. The oxide of yttrium may be dispensed with, the composition then being 50 per cent zirconia and 50 per cent oxide of lathanum. Instead of using the oxide of yttrium, ytterite earth, and instead of the oxide of lanthanum, cerite earth, containing no didymium and but little cerium, may be employed."

As a commercial article, the mantles made under this patent were dire failures; they gave a candlepower which varied from 3 to 6 candles per foot of gas consumed, and were so friable that the mantles of to-day seem giants of strength as compared with their puling forefathers. They, however, fulfilled the important function of launching the idea of the mantle, and hardly had the patents been taken out than Welsbach made the further discovery that by going outside the group of rare earths, and by replacing zirconia as a basis by thoria, increased life and strength could be given to the mantle, and this was protected by the patent taken out by Welsbach in 1886.

In this patent he protects the use of thoria alone or in admixture with zirconia, lanthana, yttria, didymia, erbia, magnesia, or alumina. During the next few years the composition of the mantles made by the Welsbach companies was of a very variable character, but the largest proportion of them consisted of commercial thoria and gave a light of 6 to 8 candles per foot of gas, this being due to the fact that the material used was not pure and contained traces of ceria, which gave it the power of emitting what was then a considerable amount of light.

Pure thoria gives a practically nonluminous mantle, and with chemically pure material the light obtainable is under 1 candle per cubic foot of gas, while even now a mantle made from the commercially pure thoria, manufactured for mantle making, gives a light of from 4 to 5 candles per cubic foot of gas, this being entirely due to the difficulty of separating the last traces of ceria; and as 0.1 per cent of ceria causes the thoria to give about 5 candles per foot of gas, it is difficult to obtain a sample which does not give a certain amount of light.

The use of ceria together with thoria is mentioned in some of Welsbach's early foreign patents, but the exact date at which it was first realized that ceria in traces had the marvelous effect on the light emissivity of the thoria mantle that we find in the mantles of to-day is not very clear, but it is evident that the advantage of the presence of small quantities of ceria was beginning to be realized by 1891, when Mr. W. McKean, the chemist of the English Welsbach Company, read a very interesting paper before the Society of Chemical Industry and pointed out that ceria is by no means a disadvantage in small quantities, as it adds to the constancy of the illuminating power, and he gives a table showing the influence of the presence of ceria in the lighting fluid, and also the influence upon the light which increasing percentages of ceria have. Thus, for instance, the ordinary lighting fluid contains 0.25 per cent of ceria, gives 25 candles for a consumption of 2.5 cubic feet of gas, or 10 candles per foot, while increasing the percentage of ceria in the fluid to 0.5 reduces this to 18 candles for 2.5 cubic feet, and when 1 per cent of ceria is added a further reduction to 13.5 candles for the 2.5 cubic feet is found; but while the candlepower lost 43.2 per cent in 1,000 hours with the 0.25 per cent of ceria, it only lost 12.6 per cent in one experiment and 28 per cent in another with 1 per cent of ceria present in the original fluid. He also gives in the same paper as a composition for a mantle giving a yellowish light: Lanthana, 40 per cent; thoria, 28 per cent; zirconia, 30 per cent; ceria, 2 per cent; showing that at this period the use of ceria in small quantities in mantles containing thoria was by no means unknown.

Later on, in 1893, Mr. Moeller, having clearly realized that commercial thoria contained traces of ceria and that it was owing to this that the earlier mantles gave any light, took out a patent in which he sought protection for thoria in combination with very small traces, not exceeding 1 or 2 per cent, of certain other rare metals, such as uranium, cerium, terbium, neodymium, samarium, praxeodymium, yttrium, and lanthanum, and the mantles of to-day nearly all consist of 99 per cent thoria and 1 per cent ceria; as although several of the oxides mentioned in minute traces endow a nonluminous thoria mantle with the power of emitting light, yet ceria so far transcends the others, not only in its power of exciting luminosity, but of keeping up the illuminating power over a long period, that as far as our knowledge goes it is needless to look beyond it.

An absolutely pure thoria mantle gives less than 1 candle per cubic foot of gas consumed, a pure ceria mantle gives but little light and of a red nature, so that for all practical purposes the ingredients when used alone are valueless, but the smallest addition of ceria gives a rapid leap up in its power of light emissivity, which reaches its maximum when from 0.9 to 1 per cent of the total oxide consists of ceria, further additions causing a rapid falling off in the light, while the light emitted first assumes a yellowish and then a reddish tint as the percentage increases.

The following curve of candlepower and percentage of ceria shows the average result obtained, but it must be borne in mind that certain traces of impurities derived from the ash of the cotton and from the salts used lower to a certain degree the absolute candlepower, although they do not affect the general contour of the curve. (Fig. 1.)

Several attempts have been made to explain the wonderful power of light emissivity possessed by the thoria-ceria mantle. Dr. Drossbach was of opinion that the rare earths had a special action in converting the heat rays into light rays, and that the molecules of ceria acted by bringing the heat vibrations of thoria to the most favorable state of resonance with the vibration of the hot flame gases. Dr. Moscheles and Dr. Killing both pointed out that cerium formed two oxides and that other metals having the same characteristics would act as exciters when used in the proper proportions, and both attributed the high incandescence of the mantle to changes in the state of oxidation increasing the intensity of combustion on the mantle surface, while Dr. Killing also pointed out that a catalytic action probably took place.

Dr. Bunte has given by far the best exposition of the theory of the incandescent mantle, which if it does not make all points clear, yet offers a simple and probable explanation of the observed phenomena, which he ascribes to intense local temperature due to the ceria exercising a power of attracting oxygen and causing its combination with the flame gases.

The remarkable influence which ceria exerts in awakening light emissivity in the mantle becomes still more remarkable when one considers that although the percentage by weight of the ceria is only 1, yet that by volume it is enormously less. When nitrate of cerium is converted into ceria by the action of heat, but little change of volume takes place, but when nitrate of thorium is decomposed in the same way its conversion into oxide is accompanied by an increase in bulk of an extraordinary character, the substance swelling up and producing a light powder occupying many times the bulk of original salt, so that in the finished mantle small indeed must be the space occupied by the exciting ceria.

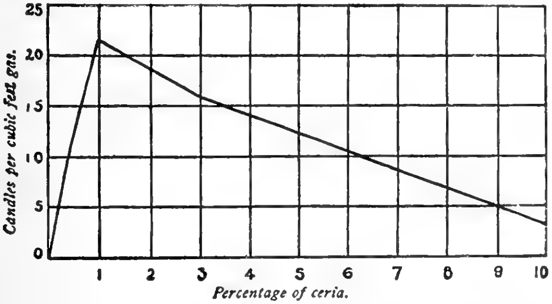

FIG. 1.—Effect of ceria upon light emission of a thoria-ceria mantle.

This seems to point to some specific action on the part of the ceria, and cases are not uncommon in which dilution with some inert material increases physico-chemical action of the kind one would expect of the ceria. If port or claret be shaken up with powdered charcoal, which consists of nearly pure carbon, and the mixture is then filtered, the color is but little changed, while if animal charcoal or some of the artificially prepared imitations of it containing less than 10 per cent of carbon distributed over the surface of inert mineral matter be used for the same purpose, the liquid is absolutely decolorized.

Another example which bears closely upon the case of the ceria is to be found in the action of platinum upon mixtures of hydrogen or coal gas and air. If a piece of platinum foil be heated to redness in a Bunsen flame, and the gas be then turned out and again turned on before the platinum has had time to grow too cool, it again becomes heated to redness in the stream of gas and air and continues in that condition as long as the gases are passing over its surface, while if brought to what would have been the outer envelope of the flame had the gaseous mixture been alight, the temperature is so increased that the ignition point of the gas is reached. The action here is what is known as catalytic or surface action, and is due to the fact that platinum has the power of condensing gases upon its surface, and in doing so renders them so chemically active that combination between the condensed gases is often induced, and in the case of the coal gas and air enough heat is evolved on the surface of the platinum to raise it to redness. The result being due to surface action, it is manifest that an increase of the surface must increase the activity of the substance, and if, instead of taking metallic foil with its comparatively small area of exposed surface, spongy platinum made by reduction from platinum salt or asbestus coated with the reduced metal be employed, ignition of the gaseous mixture without the preliminary heating takes place.

The fact that the platinum foil remains red hot in the stream of coal gas and air, which is only at atmospheric temperature, at once shows that the heat evolved by such an action is localized in the body starting the action, and it is manifestly possible, and indeed probable, that the very minute particles of ceria scattered over the surface of the inert thoria and so subdivided as to be capable of easy and rapid heating to a very high temperature may give rise to an action of the same kind. Indeed, one knows that to a certain extent this is so, because if the mantle burner be turned off and again turned on while the mantle is still hot, the mixture of gas and air is reignited, although the rod and mantle material are manifestly below the ignition point of the gas, and the fact that this does not take place with a pure thoria mantle is a fairly good proof that it is the ceria and not the thoria which is acting.

Dr. Bunte has found that thoria had no influence in bringing about the combination of hydrogen and oxygen, and the temperature at which the two combined to form water was the same whether thoria was present or not, but that the presence of ceria caused them to combine at 600° F. instead of 1,200° F. This being so, the question arises as to what the action can be that the ceria induces, the localization of the heat from which causes its minute and subdivided particles to glow with so high an incandescence.

When in a Bunsen burner the admixture of gas and air has been carried to the extreme limit, so that what would have been the inner cone of the Bunsen flame settles down as a green and seething sheet on the gauze of the burner top, being indeed only prevented from flashing back in the tube by the conducting power of the gauze and the accelerated rush of the gas and air mixture through its meshes, the combustion is being completed in two stages, the first taking place on the surface of the gauze where the hydrocarbons of the coal gas undergo incomplete combustion at the expense of the oxygen of the admixed air yielding carbon monoxide and hydrogen, together with small quantities of carbon dioxide and water vapor, and it is the combustion of the carbon monoxide and hydrogen which gives the outer flame in which the mantle is heated, this combustion entirely taking place at the expense of the oxygen derived from the air surrounding the flame and not from the air originally mixed with the gas in the burner tube. It is a mistake to speak of this outer flame as a "solid flame," an expression often used in connection with burners in which sufficient air is introduced with the gas to flatten the inner zone onto the gauze, as it is merely the structureless flame which is always obtained on burning gases like carbon monoxide and hydrogen which burn only in one stage. Any user of mantles knows perfectly well that it is only in the edge of this outer flame that the mantle material acquires its true incandescence, this being due to the fact that it is only when the maximum quantity of air and the carbon monoxide and hydrogen meet that the highest temperature is attained, and it is here that combustion is at its fiercest and that the catalytic action of the ceria creates points of high intensity.

The view put forward by Moscheles and Killing may be shortly stated as follows: Cerium is a metal which exists in two states of oxidation, a lower or cerous oxide, Ce_2O_3, and a higher or ceric oxide, CeO_2, and it is easily conceivable that in its highly subdivided condition and at a high temperature, exposed as it is to the high reducing action of hydrogen and carbon monoxide, which tend to take oxygen from it and convert it into cerous oxide, and also to the oxidizing action of the air, which tends to again build it up into ceric oxide, a continual oxidation and reduction is taking place, the abstraction of oxygen from the air and its liberation to combine with reducing gases on the surface of the ceria raising these attenuated particles far above the temperature of the flame.

It is quite clear that whether one accepts the Killing theory of dual oxidation, or Bunte's of catalytic action of the ceria, one arrives at an explanation of the fact that unless the mantle be just in the right position so that both the air and flame gases have access to it, the luminosity is practically destroyed.

It may be roughly stated that there now exist two classes of theory with regard to the mantle, the first being that the ceria or ceria and thoria exercise some occult power in converting heat rays into light, and the second, the theories of Killing and Bunte, which ascribe the wonderful light emissivity to the exalted temperature brought about by local combination due to the power of the ceria in attracting oxygen, and it matters but little whether this be brought about by a purely chemical or by a physicochemical action.

It is clear that if the light be due to the conversion of heat rays into light, on heating the material out of contact with air, the same differences in their power of emitting light should be observed as exist in the mantle, and several experiments have been made in order to find if this were so or not.

Dr. Bunte took a thick-walled tube of arc carbon, having the walls of its middle portion reduced for a length of 4 inches to a thickness of 0.059 inch, and heated it by an electric current until the middle portion attained a most intense white heat far above 3,630° F. In order to prevent combustion and loss of heat, the middle of the tube was embedded in magnesia, over which asbestus was wrapped. Small square prisms—0.59 inch long by 0.28 inch wide—of magnesia were coated with the substances to be examined, and each was cemented to a similarly shaped piece of carbon or magnesia, so that the two adjoining faces consisted of the two substances to be compared. On placing these double prisms in the tube it was possible with certain precautions to observe the relative intensities of the radiation by comparing the two halves of the surface visible in the tube. These researches showed very small differences in the intensity of the radiation from carbon, magnesia, pure oxides of thorium and cerium, and the Welsbach mixture.

Within the last few weeks confirmation has been given of Dr. Bunte's results by an extremely interesting paper communicated to the Royal Society by Mr. A. A. C. Swinton, in which he inclosed the luminous materials in a vacuum tube and subjected them to bombardment by means of cathode rays which would raise them to a very high temperature, as it is possible by such a method to melt platinum and glass and bring finely divided carbon to bright incandescence. The mantle to be experimented on was mounted on a platinum wire frame and placed between the two electrodes, so that as the electric current alternated and each electrode became in turn the cathode the mantle was subjected on alternate sides to cathode-ray bombardment. Experiments were made with mantles consisting entirely of ceria and thoria, both separate and mixed in different proportions, and in order to obtain accurate comparisons between the pure oxides and different mixtures the mantles were made in patchwork, each mantle being made up of two or four sections separately impregnated with different solutions and then sewed together with impregnated cotton before being burned.

With a compound mantle prepared in this way, composed one half of pure thoria and the other half of a mixture of 99 per cent thoria with 1 per cent ceria, it was found that after exhaustion on starting the cathode discharge the thoria plus ceria heated up to incandescence more rapidly, and on stopping the discharge cooled more rapidly than the pure thoria. Further, when at full incandescence and observed through a dark glass the thoria plus ceria was slightly more luminous than the pure thoria, though the difference was very small, probably not more than 5 per cent. Owing to the difficulty of obtaining a constant vacuum, accurate photometric measurements were not possible, but the amount of light under favorable conditions was roughly estimated as at least 150 candlepower per square inch of incandescent surface, this being obtained with an expenditure of electrical energy in the secondary circuit of about 8,000 volts pressure of approximately 1 watt per candle. The amount of exhaustion suited to give the best results varied with the dimensions of the tube and the conditions mentioned in the paper, but was approximately about 0.00005 atmosphere, the maximum luminosity being obtained when the dark spaces of the two cathodes just crossed at the center of the bulb. Owing to the large amount of gas occluded by the mantle, a proper degree of permanent exhaustion was very difficult to arrive at, and required continuous pumping for many hours, with the cathode rays turned on at intervals.

Even then the conditions of maximum luminosity were exceedingly unstable, owing to the further liberation of occluded gas on the one hand and on the other to the rapid increase in the degree of exhaustion, owing to absorption of the residual gas by the electrodes. That such absorption probably took place in the aluminum electrodes and not in the mantle was demonstrated by other experiments with a tube in which there was no mantle, but only two electrodes of aluminum wire.

These experiments all point to the fact that the idea of a mixture of 99 per cent thoria and 1 per cent ceria having the peculiar power of converting heat rays into light, while thoria and ceria alone have not this power, or at any rate only have it to a very limited extent, is not tenable, as otherwise the same difference would have been noticed when the materials were heated either in the carbon-tube furnace or in the vacuum tube, and this undoubtedly gives great support to the second theory.

It has been pointed out that the amount of ceria in the mantle is so extremely small that it seems hardly credible that any surface action that it possessed would play an important part in the production of luminosity, but Dr. Bunte answers this objection by saying that "according to Davy's theory, the illuminating power of an ordinary gas flame is due to particles of carbon which are separated from the gas and raised to a white heat. The carbon arises chiefly from the decomposition of the heavy hydro carbons ethylene and benzene, which form together about 5 per cent of the volume of the gas.

Assuming, for the sake of simplifying the calculation, that all the carbon of the benzene and half that of the ethylene is separated and heated to incandescence in the flame, it may be calculated that about 54 milligrammes of carbon are separated from a liter of good coal gas (23.6 grains from 1 cubic foot). Thus 4 per cent of ethylene and 1 per cent of benzene gives per liter of gas 60 cubic centimeters of carbon vapor from the benzene and 40 cubic centimeters from the ethylene, in all 100 cubic centimeters, which is equivalent to about 54 milligrammes of carbon. The volume of the luminous portion of a flame having a consumption of 5.297 cubic feet per hour and an illuminating power of 17.5 candles is about 2 centimeters at 32° F. There is, therefore, in it $\frac{2 \times 54}{1.000}$ milligrammes, or 0.1 milligramme=0.0015 grain of incandescent carbon. Such an extremely small quantity of incandescent carbon as 0.0015 grain gives the luminous surface to the gas flame and emits a light of 17.5 candlepower. Now, the 1 per cent of ceria in the Welsbach mantle amounts to about 4 milligrammes (0.06 grain) per mantle, or about forty times the quantity of incandescent carbon in an ordinary flat flame. The quantity is, therefore, quite sufficient to explain why the Welsbach burner may give a light of 60 candles while the flat flame, or Argand burner, furnishes only 17.5 candles."

The only other legalized mantle at present before the public is the Sunlight, the ingredients of which consist of alumina and the oxides of chromium, and it is interesting to see how far the light yielded by this mantle can be attributed to the same action as in the case of the Welsbach. If a mixture of alumina or alumina and zirconia with a very small percentage of chromium be employed, a very high candlepower is produced, which, however, soon dies away, owing to the volatilization of the chromium compound, while if the amount of chromium present be increased, the mantle acquires a more ruddy light and retains its illuminating power for a much longer period, so that, with a proper percentage of chromium, a candlepower of 10 to 11 candles per cubic foot of gas can be obtained for a period of 400 to 500 hours, and it is noticed that the chromium, which on first burning shows as green chromium oxide, rapidly combines with the alumina to form a pink compound which has much the same composition as the ruby, and it is quite probable that the increased life given by the larger quantity of chromium is due to the fact that the lighting power of the mantle is really dependent on small traces of the oxide of chromium, and that as this gradually volatilizes off from the surface of the mantle some of the pink compound gets dissociated by heat and supplies a fresh portion of chromium oxide to the surface of the mantle, this pink compound being far less volatile than the chromium oxide itself.

Thoria, as far as the life of the mantle goes, is perhaps the most important constituent, as there is no other known oxide which will stand heat for so long a period without being affected by it, and the getting away from shrinkage in the mantle was one of the chief steps which led from the failure of the early mantles to the success achieved by the later ones.

Moreover, thoria is a body having a very low specific heat, and owing to its bulk when produced from the nitrate of thorium by the action of heat is a good nonconductor, so that the temperature created on the surface of the ceria particles is more readily localized there.

Within the last few years attempts have been made to attack the question of mantle making from a different standpoint. Admitting the superiority of thoria with its 1 per cent of ceria over other mantle mixtures, efforts have been made to obtain mantles of filaments of this mixture upon the principle under which the old Clamond basket was made.

Clamond produced his incandescents by making a paste of magnesia with acetate of magnesia in solution, and molded the mixture into threads by squeezing through holes in a plate, the threads while still moist and plastic being wound to the required shape on a mandrel or mold, the still moist threads being pressed together and made to cohere at the points where they crossed each other, and then on baking the acetate luting burnt to oxide and the coherent magnesia hood or basket remained.

The reduction in size of the filaments to be rendered incandescent was a great advance over the old lime light and enabled incandescence to be produced by a burner instead of a blowpipe, while Welsbach's discovery, or rather adaptation of the principle of saturating a fabric and incinerating, created a new era in incandescence by giving a degree of fineness not before approached.

As was natural, attempts were then made to reduce still further the size of the filaments in the Clamond basket, and on November 4, 1890, Lungren patented a distinct advance. It was found that if you made a plastic filament as Clamond had done, but finer in substance, it dried very quickly, and on attempting to make the material cohere at the crossing of the threads, those first wound on the mandrel, being drier than those wound across them, were harder, and on pressure being applied cut through the softer threads instead of welding with them. Finding this, Lungren patented the idea of making a plastic mass of some elastic material charged with refractory earths or metallic oxides, expressing from some such mass fine wires or threads, weaving or interlacing the threads into a fabric from which the cone or mantle could be made and then burning out the combustible elastic binder. In making this binder he gives mixtures of glue with glycerin, india rubber dissolved in naphtha, or boiled linseed oil as examples, but also says that a variety of materials may be used.

One of the most remarkable developments of the last fifty years has been the wonderful way in which the lower form of gun cotton, known as collodion cotton, has been utilized for commercial purposes, and at the present time it bids fair to invade the territory of incandescent mantle making. It was in 1838 that the chemist Pelouze drew attention to the fact that when paper was acted upon by the strongest nitric acid it increased in weight and acquired the property of burning with enormous rapidity, while as early as 1832 Braconnot had prepared a substance called "xyloidin" by acting upon starch, linen, and sawdust in the same way. It was not, however, until 1845 that any serious attention was directed to the use of such substances as explosives, when Schonbein first called attention to nitrated cotton wool and advocated its use as a substitute for gunpowder, showing that in explosive energy it was far superior to it.

Experiments were at once instituted on a large scale and its manufacture carried on in England and also on the Continent, but in 1847 a very serious explosion occurred at the works in which it was manufactured by the Messrs. Hall, at Faversham, while a year later an even more serious explosion followed in the gun-cotton factory at Bouchet, near Paris, and as no reason could be assigned for these and other similar explosions, gun cotton was looked upon as too dangerous an explosive for ordinary use, and its manufacture was for a time discontinued.

During this brief period, however, it had been discovered that if the strength of the nitric acid employed in the manufacture were slightly reduced, a compound was formed which had the property of dissolving in a mixture of alcohol and ether, which was not the case with the true gun cotton, and that on allowing the solvent to evaporate, a semitransparent mass was left in which no trace of the structure of the original material remained. This solution was eminently adapted for forming thin films on glass plates, and as this was a great desideratum at this particular period for photographic purposes, the new material began to be manufactured on a fairly large scale. It was soon found that by slight modifications in the method of manufacture and by loading it with various foreign materials, excellent imitations of amber, ivory, and tortoise shell could be obtained, with the result that the manufacture of collodion has now attained considerable importance.

One of the most beautiful applications of collodion is the manufacture from it of artificial silk. In the interesting but little-known town of Besançon, the French inventor Chardonet has established a manufactory in which collodion made by nitrating wood pulp is dissolved in the smallest possible quantity of alcohol and ether, and the emulsion is then squeezed out under a pressure of 750 pounds to the square inch through capillary glass tubes, the clear way of which is less than one-hundredth of a millimeter, this enormous pressure being required to cause the material to flow evenly through the excessively small apertures. The filaments of from ten to twelve of these tubes are then twisted and wound on to a bobbin in a machine of the same character as used for the spinning of silk fiber. The air of the room in which this operation is carried out is kept at a sufficiently high temperature to cause the instantaneous setting of the filaments owing to the evaporation of the alcohol and ether, so that within 3 or 4 inches of the tube from which the material is issuing it has lost all stickiness and may be twisted without cohesion between the threads. These threads have all the appearance of silk, but have one serious drawback, that being practically a low form of gun cotton, they are excessively inflammable and burn with a violence only a little removed from that of true gun cotton. In order to overcome this trouble, the skeins of artificial silk are soaked in ammonic sulphide, which has the effect of what is termed "denitrating" them and converting them once more into cellulose, so that after washing and drying the material is not more inflammable than an ordinary fabric. This material is capable of taking every shade that the dyer's art can impart to it and forms a most beautiful and wonderful imitation of silk, lacking only to a slight degree the elasticity found in the original article.

This extremely beautiful process was brought to perfection by Chardonet and protected by him during the period which extended between 1886 and 1893, and in 1894 De Mare took out a patent for making incandescent filaments by charging collodion with metallic salts and oxides, squeezing into threads, weaving, and burning. In this patent, however, he makes no mention of denitrating the collodion filaments before burning, which would make it extremely difficult to make a mantle according to his patent.

In 1895 Knoffler patented the manufacture and denitration of collodion threads or filaments loaded with oxides or salts, and in his first claim mentions that the filaments may be "individual or spun and eventually wrought or woven threads which are made after the manner of the so-called artificial silk."

Later on Plaissetty took out a patent which differs from Knoffler's only in that he uses glacial acetic acid as the solvent for his collodion cotton, and instead of denitrating with ammonic sulphide, uses a solution of sulphide of lime, which, however, has the drawback of leaving a trace of lime as an impurity in the finished mantle.

Mantles made by such methods as those devised by Knoffler and Plaissetty are developments of the Clamond hood and not of the Auer mantle, the difference being that whereas the Clamond class consists of filaments of even density made by squeezing a plastic material into rods or threads which, after the binding material is burned off, leave a uniform mass of oxide, the Auer class consists of filaments having a dense central portion surrounded by a more or less spongy coating, due to the fact that the soaked fabric on burning off leaves the oxides produced from the interior of the capillaries in a dense state while the salt on the exterior of the cotton in its conversion into oxide by heat is rendered spongy by the escape through it of the gaseous products of the combustion of the cotton, so that if a section of one of the filaments constituting a strand could be examined under the microscope, the appearance would be somewhat as described. The physical effect of this on the mantle is that the Clamond class is harder than the Auer and does not show the same high incandescence until the surface of the filaments has become eroded by burning for a short period, the life of the Clamond class when made of the same material as the Auer, however, being longer. For instance, two mantles made one by the Plaissetty and one by the Auer method so as to yield an ash containing 99 per cent thoria and 1 per cent ceria would give curves of the following character (fig. 2), the total life of the Knoffler and Plaissetty mantles being probably a third longer that of the Auer:

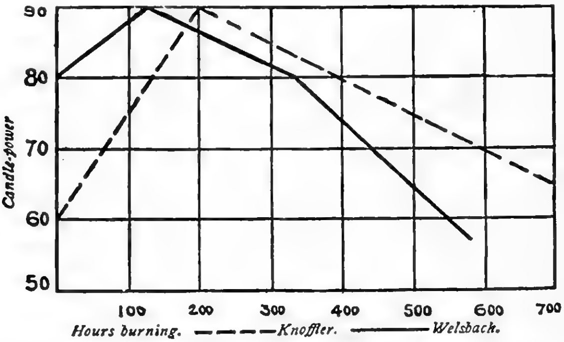

FIG. 2.—Endurance of Welsbach and Knoffler mantles compared.

There seems every probability that mantles of Knoffler and Plaissetty type will play an important part in incandescent lighting, as in Paris the Welsbach Company has acquired the patent rights of the process and is introducing an innovation upon it. On taking a collodion mantle and heating it in a drying oven for a certain length of time a considerable shrinkage takes place, and if this shrunken mantle is then placed on a burner and burnt off the fabric rapidly moulds itself to the form of the flame with but little manipulative aid. For street lighting and for maintenance work it would manifestly be a great convenience to do away with the collodionizing altogether, which always, to a certain extent, impairs the light-giving power of the mantle.

Another new feature which has been introduced into mantles of this class is the doing away with the asbestus thread and loop, which has always been a weakness in the fabric, and to make the strangulation at the top of the mantle by sewing it around with fibers of the same character as those of which the mantle itself is made, this constricted annulus then resting upon a supporting ring which is fixed as the ordinary support in the center of the mantle.

The asbestus thread has always weakened the top of the mantle owing to the difference in the rate of contraction during burning off, and with a mantle merely resting on a supporting ring in this way you get what is really an antivibrating arrangement which materially enhances the life of the mantle for outside work.

The matter which I have brought before you has already occupied so much time that I do not propose to go into the question of burners. Many highly vaunted improvements have been introduced during the last two years, but they have all been based upon the idea first introduced by Bandsept of getting the proper admixture of the maximum of air and gas to be burned at the bottom of the burner and completing and perfecting the mixture close to the mouth of the burner where the combustion is to take place.

In many cases the increased luminosity given by such burners is really due to the length of tube, the increase of which acts in the same way as increase in gas pressure. These improved burners have shown themselves to be extremely variable, as while with carefully adjusted samples and careful manipulation in the laboratory it has been possible to get as much as twenty-five candles per foot of gas with a properly prepared Welsbach mantle, yet in practice on a big scale the duty given is quite as often seventeen candles or less, and the old Bandsept burner, when properly made, is still as good as or better than any of the new ones.

THE IMPERIAL PHYSICO-TECHNICAL INSTITUTION IN CHARLOTTENBURG.[1]

By Henry S. Carhart.

I. HISTORICAL.

Through the courtesy of Professor Kohlrausch, president of the Reichsanstalt, and the curatorium or governing body of the institution, the writer was accorded the privilege of working in the Physikalisch-Technische Reichsanstalt as a scientific guest during the last few months of 1899. An unusual opportunity was thus afforded of learning rather intimately the methods employed and the results accomplished in this famous institution for the conduct of physical research, the supply of standards, and the verification of instruments of precision for scientific and technical purposes.

It is well known that the Reichsanstalt is situated in Charlottenburg, a suburb of Berlin just beyond the renowned Thiergarten. The buildings occupy an entire square, the larger part of which, valued at 500,000 marks, was the gift of Dr. Werner Siemens. In making this gift, which was offered in land or money at the option of the Government, Dr. Siemens declared that he had in mind only the object of serving his fatherland and of demonstrating his love for science, to which he avowed himself entirely indebted for his rise in life. The gift was made as a stimulus to the Government to establish an institution for physical research. The kind of institution desired had been amply described in suitable memorials prepared by himself, Professor von Helmholtz, and others of scarcely less distinction. The first memorial bears date of June 16, 1883. It relates to "The founding of an institution for the experimental promotion of exact natural philosophy and the technical arts of precision." It points out the need of such an institution, details the benefits likely to accrue from it, lays great stress on the intimate relation existing between scientific investigations and their application in the useful arts, and sets forth somewhat in

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[1] A paper presented at the one hundred and forty-sixth meeting of the American Institute of Electrical Engineers, New York, September 26, 1900. President Hering in the chair. Reprinted from Transactions of the American Institute of Electrical Engineers, Vol. XVII, Nos. 8 and 9, August and September, 1900.

detail a plan of organization. The memorialists had in mind at that time a "physico-mechanical institution," but in a memorial of the following year (March 20, 1884) the title was changed to the one which the institution now bears—"Physikalisch-Technische Reichsanstalt." From this second memorial it is learned that the first steps toward the furtherance of exact science and technical precision in an institution to be founded and maintained by the State were taken as early as 1872. This movement had the support of the crown prince, the late Emperor Frederick, and the matter was taken in hand by Count von Moltke as chairman of the central bureau of metrology in Prussia. He called together a commission near the end of the year 1873, and in the following January this commission reported a series of propositions for the improvement of the scientific mechanic arts and of instruments of precision. These propositions formed the foundation for a memorial on the same subject to the Chamber of Delegates of the Prussian Government in 1876. The result was that appropriate rooms were set aside in the new building of the Technical High School in Charlottenburg for the organization of an institution for the cultivation of the arts of precision.

The general plan of the Reichsanstalt was adopted in 1887, and an appropriation of 868,254 marks was made and spread over the budget for three years. The main building for the first or scientific division was completed in 1893. The second or technical division was housed in a portion of the Technical High School till the buildings for this division were completed, in 1897. All departments of activity of the Reichsanstalt are now accommodated on the square facing on March strasse in Charlottenburg. They include the division for pure scientific research, mechanical measurements of precision, electrical measurements and instruments, the measurement of large direct and alternating currents and electromotive forces, the optical department, the department of thermometry, the department of pyrometry, and the department of chemistry. To these as auxiliaries should be added the power plant and the workshop.

II. ORGANIZATION.

The two divisions into which the Reichsanstalt is divided correspond to the two paramount objects which the founders had in view, viz, research in pure science and the cultivation of precision in the technical applications of science. The same idea is embodied in the very name of the institution—The Imperial Physico-Technical Institution. If the sole purpose of the Anstalt had been the promotion of improvements in the mechanic arts, in engineering, and in instruments of precision, the first, or scientific, division would still have been essential to secure the ends sought. All the applications of science rest on the foundation of pure scientific discovery. The creation of new and improved methods and instruments for physical measurements requires the most exhaustive and painstaking investigations as a preliminary to a steady and confident advance. The practical value of research in pure science is no longer in question. The wise founders of the Reichsanstalt made no mistake in coupling an institution for the promotion of technical precision with one for the prosecution of research in physical science.

The governing body, or curatorium, of the Reichsanstalt is appointed by the Emperor. At its head is Herr Weymann, imperial privy counselor. The function of the curatorium is the appointment of the officials and the general management of the institution. The chief officer of the Reichsanstalt is the president, and the most distinguished physicist of the realm is sought for this position. Helmholtz was taken from the university in Berlin to become the first incumbent of the office. After his death, in 1894, his successor as professor of physics in the university, Prof. F. Kohlrausch, became his successor as president of the Reichsanstalt.

The president, who is at the same time director of the first division, is held responsible for the successful work of the Reichsanstalt. All other officials are therefore subordinate to him. In his absence the duties of his office devolve upon the director of the technical division. Subordinate to the director of this second division are the professors, associates, and assistants of various grades. A professor in charge of a department has the direction of all those employed in it, including a skilled departmental mechanician.

The specific duties of the president may be briefly enumerated. He must lay before the Curatorium at its annual meeting the following:

1. A report on the work executed in both divisions.
2. The plan of work for the undertakings to be carried out the ensuing year.
3. Propositions relative to the money to be expended for scientific and technical work; also for salaries and remunerations.
4. Propositions relative to the rank of permanent associates and assistants; also relative to the bestowal of places to work in the Reichsanstalt as scientific guests.

He takes a vote on the propositions in 3 and 4, and reports the conclusions of the Curatorium to the Government for approval. It is also the duty of the president to sign vouchers for all payments, and he is held responsible for the proper expenditure of the money appropriated for the maintenance of the institution.

The different functions of the two divisions composing the institution are defined in rather broad terms. It is the duty of the first division to carry out physical investigations requiring more uninterrupted time on time part of the observer, and better accessories in the way of instruments and local appliances, than private individuals and laboratories of institutions for teaching as a rule can offer. These investigations shall be carried out partly by officers of the Anstalt and partly, under their oversight, by scientific guests and voluntary workers. By scientific guests in general are meant the holders of scientific positions in the German Empire, who wish to prosecute scientific researches, the plan of which they have submitted, and for which they have not at home the necessary appliances. They must be recommended by the State in which they reside, and must be accepted by the Curatorium.

Young men may be accepted as voluntary workers who have proved their ability by scientific publications. They will undertake researches which have been determined upon by the Curatorium or the director; or they may investigate subjects which they themselves suggest, and which appear to the director to be practicable and worthy of execution. The scientific results obtained must be published only at the discretion of the authorities of the institution, who reserve also the right to publish them in the researches of the Reichsanstalt. Provision is made that voluntary workers shall not use the institution for private ends nor to obtain patents.

The second division of the Reichsanstalt is placed under a director, who is subject to the higher authority of the president. Such a director was considered necessary on account of the special work of this division, as well as because of the intimate relations into which it is brought with many persons engaged in industrial pursuits. He should therefore not only be a scientific man but should at the same time have some technical knowledge of the applications of science. Under the director are placed the permanent heads of the subdivisions of the technical department, one having the oversight of thermometry, one of optics, two of electricity, and one of mechanical measurements of precision. Along with these, and of the same rank and compensation, is the director of the workshop. Under him at present are eight mechanics, and the shop is provided with the finest tools for the execution of the most exact work required by the institution. For example, it has a circular-dividing engine that cost $2,500. The founders of the Reichsanstalt foresaw the necessity of such mechanical aids for the furtherance of the exact work to be undertaken. They wisely concluded that such special constructions and new types of instruments as they might require from time to time could be more conveniently and more cheaply built in their own shop than by private instrument makers.

III. COST AND MAINTENANCE.

The following are the official accounts of expenditures for the grounds, buildings, furniture, and instruments for the two divisions, to which are added the yearly expenses:

DIVISION I.

	Marks.	
1. Acquisition of ground, the gift of Dr. Werner Siemens	500,000	
2. For erection of buildings:		
a. Main building	387,000	
b. Machinery building	50,000	
c. Administration building	100,000	
d. President's house	99,254	
e. Grading, paving, etc	10,472	
f. Paving half of street	30,274	
g. Building for battery	8,500	
3. Fittings and furniture	58,000	
4. Equipment of machinery and instruments	82,310	
		1,325,810

DIVISION II.

1. Acquisition of ground	373,106	
2. Erection of buildings:		
a. Main building	922,000	
b. Laboratory building	218,000	
c. Machinery building	180,000	
d. Dwelling for officials	140,000	
e. Additional improvements	348,000	
3. Fittings and furniture	108,300	
4. Equipment of machinery and instruments	471,390	
	2,760,796	
Less reduction for 1895–96	47,500	
		2,713,296
Divisions I and II together		4,039,106

The annual expenditures for 1899 were as follows:

	Marks.
1. Expenditures for salaries and laborers	206,604
2. Miscellaneous articles, experimental work, and care of buildings	127,000
Total	333,604

The receipts for calibrating instruments, testing materials, verifying standards, and the like now amount to about 40,000 marks annually. This sum should be deducted from the yearly expenditures, leaving a net sum of about 300,000 marks.

In round numbers the Reichsanstalt has cost $1,000,000, and the annual appropriation for its maintenance is $75,000.

IV. RESULTS.

A very pertinent inquiry is, What are the results of all this expenditure? Might not more good be accomplished by State aid to some existing technical school or university? The results attained must be set by the side of the objects which the founders of the institution had in view in order to ascertain whether the sequel has justified their predictions. In the memorials to which reference has already been made Professer von Helmholtz and Dr. Werner Siemens pointed out the advantages likely to accrue to Germany from the maintenance of an imperial institution for research, which should at the same time assume the cognate function of fixing and certifying standards of mechanical and physical measurements. Attention was drawn to the fact that other countries, notably England, had enjoyed great renown in science because of the brilliant researches and discoveries of some of her scientific men who had the good fortune to be possessed of leisure and large private means and the scientific spirit to devote them to investigations demanding both as a sine qua non.

These conditions the memorialists declared were lacking in the fatherland. Her scholars who had the enthusiasm and the capacity for exact scientific investigation possessed neither the private fortune to devote to it nor the uninterrupted time for the execution of the work. They were to be found among the men engaged in teaching, but their professional duties absorbed their time to such an extent that only an inadequate residue remained; and even that little was divided into fractions too small to admit of the sustained and continuous attention which any important investigation demands.

It was further pointed out that if the Government would supply the conditions favorable to scientific discovery, the men could be found whose work would reflect great credit on the State, while the interaction between pure science and its applications to arts and manufactures would put Germany in the forefront of scientific renown and of the intelligent application of science to useful purposes.

It was further urged by von Helmholtz that the brilliant investigations of Regnault and other French physicists many years ago should now be repeated with the superior methods and instrumental appliances available at the present time. These investigations drew the attention of the scientific world to France and made it the focus of scientific interest. Her instrument makers, even up to the present, have reaped a rich reward in foreign orders for instruments made eminently desirable and almost indispensable by these distinguished French investigators.

Other problems, too, needed solution—problems forced to the front by modern requirements and discoveries. The applications of electricity, for example, present new questions for science to answer, while the interests of the consumer at the same time call for some form of control by the State of the instruments employed in fulfilling contracts. The very units in which such measurements are made need to be authoritatively settled—a task demanding the highest manipulative skill in experiment and the most refined appliances which experience can suggest and money purchase.

The German Government admitted the force of these considerations and made splendid provision, both for pure science and its technical applications, by founding the Imperial Institution at Charlottenburg. The results have already justified in a remarkable manner all the expenditure of labor and money. The renown in exact scientific measurements formerly possessed by France and England has now been largely transferred to Germany. Formerly scientific workers in the United States looked to England for exact standards, especially in the department of electricity. Now they go to Germany. So completely has the work of the Reichsanstalt justified the expectations of its founders, and so substantial are the products of this already famous institution, that other European nations are following Germany's example. Great Britain has already made an initial appropriation for a national physical laboratory, to be organized on a plan similar to that of her Teutonic neighbor. Mr. R. T. Glazebrook, who has long served as secretary of the electrical standards committee of the British Association for the Advancement of Science, has been appointed director and has entered on his duties. The new institution will absorb the old Kew Observatory, and other buildings will be added at once for the extension of the functions of this observatory so as to include the larger enterprise contemplated in the establishment of the new national laboratory.

Russia also has a number of large and well-equipped laboratories in connection with her central bureau of weights and measures. One of these is devoted to the verification of instruments for electrical measurement. It employs fourteen men, and the budget is about $45,000 per annum.

France is also moving in the same direction. The great service of France in fixing standards of length and mass has long been freely recognized by the civilized world. But her national bureau for this purpose is now considered to be too limited in scope to solve the new problems presented. Quite recently a committee of learned men from Paris, under the leadership of Minister Bourgeoise, visited Charlottenburg for the purpose of examining into the working of the renowned institution located there. Professor Violle, one of the most illustrious physicists of the French capital, accompanied the committee. What better evidence of the success of Germany's great institution can be demanded than the consensus of favorable opinion among those best qualified to judge that its fruits are already of the highest order of merit and its imitation by other European nations the sincerest form of flattery?

It would not be just to form an estimate of the success of the Reichsanstalt without taking into account its scientific publications. These are numerous and of great value. Most of the reports of work done are made public with official sanction in various scientific and technical journals. During the past year thirty such papers have been published. The detailed accounts, however, of the most important undertakings thus far completed are contained in three quarto volumes of investigations. Among those contained in the first two volumes may be mentioned papers pertaining to thermometry and to units of electrical resistance.

The investigations in thermometry comprise such topics as the influence of the glass on the indications of the mercurial thermometer, division of the thermometer, and determination of the errors of division, determination of the coefficient of outer and inner pressure, determination of the mean apparent coefficient of expansion of mercury between 0° C. and 100° C. in Jena glass, and investigations relating to the comparison of mercurial thermometers.

Four papers of exceptional value relate to normal standards of electrical resistance. They are the probable value of the ohm according to measurements made up to the present time, the determination of the caliber correction for electrical resistance tubes, the normal mercury standard ohm, and the normal wire standard ohm of the Reichsanstalt. When one recalls that the ohm as a practical unit of measurement is defined in terms of the resistance of a specified column or thread of mercury, it will readily be seen that the work done at Charlottenburg in this particular field is fundamental in character and of the most universal importance.

In passing it is worthy of remark that all the standard resistances designed and constructed at the Reichsanstalt are carefully compared with the mercurial standards early in each year. This custom is in accordance with the action taken by the electrical standards committee of the British Association at Edinburgh in 1892, when the mercurial standard was definitely adopted. At this meeting of the committee representatives of American, French, and German physicists (including Von Helmholtz) were invited to sit as members. The methods employed in these comparisons and the forms of the standards are original with the Reichsanstalt. The new forms and methods admit of a combined accuracy and convenience not previously attained.

In addition to the work done in electrical resistance, the investigation of the silver voltameter and the electromotive force of standard Clark and Weston cells has been highly productive of useful results for the other two fundamental electrical measurements. Much remains to be done in this latter direction, for the electromotive force assigned to the Clark and the Weston cell, even in the latest report of the Reichsanstalt, is derived from neasurements by the silver voltameter, while the electrochemical equivalent of silver is in doubt to a greater extent than the electromotive force of the Clark cell.

Perhaps the best indication of the valuable work of the Reichsanstalt is to be found in the annual "Thätigkeitsbericht." This report of the years' activity is published in the "Zeitschrift für Instrumentenkunde," and the reprint for 1899 forms a pamphlet of twenty-five large, closely printed pages. The following abstract will convey some impression, though an imperfect one, of the extent of the work accomplished.

First (Physical) Division.

I. *Work in heat.*—Determination of the density of water between 0° C. and 40° C.

Determination of the pressure of water vapor at low temperatures.

Determination of the pressure of water vapor near 50° C.

Investigation of thermometers for temperatures between 100° and 200° C.

Investigation of the nitrogen thermometer with a platinum-iridium bulb for very high temperatures.

Investigation of thermometers for low temperatures.

Determination of the thermal and electrical conductivity of pure metals. (These determinations are to be extended down to the temperature of liquid air and up to 1,000° C.)

Investigations with the Fizeau-Abbe dilatometer.

Investigation of the transmission of heat through metal plates.

II. *Work in electricity.*—Comparison of the normal wire resistances of Divisions I and II.

Determination of the capacity of an air condenser.

Comparison of the standard cells of Divisions I and II.

Determination of the conductance of water solutions with a higher degree of accuracy than has been attained hitherto, especially with very dilute solutions.

III. *Work in light.*—Investigation with electrically heated black bodies.

Proof of Stefan's law between 90° and 1,700° absolute temperature.

Determination of the relation between the intensity of light and the temperature.

Measurement of radiation in absolute measure.

Determination of the distribution of energy in the spectrum of black bodies.

Determination of the distribution of energy in the spectrum of polished platinum and other substances; also their reflective power.

Second (Technical) Division.

I. *Work of mechanical precision.*—Investigation of the errors of length and of the division of 300 scales, tubes, etc.

Coefficient of expansion of 18 bars, tubes, and wires.

Verification of 86 tuning forks for international pitch.

Construction of a new transverse comparator.

Study of the variations of angular velocity of rotating bodies.

II. *Electrical work.*—Calibration of direct-current apparatus, 183 pieces.

Calibration of alternating-current apparatus, 58 pieces.

Examination of other electrical apparatus, 76 articles.

Examination of accumulators, primary elements, and switches, 37 articles.

Examination of insulating and conducting materials and carbons, 23 articles.

Installation of storage cells for a current of 10,000 ampères.

Installation of small storage cells for an electric pressure of 20,000 volts.

Installation of alternating-current instruments for measuring potential difference up to 500 volts and current up to 100 ampères.

Examination of 29 samples of alloys for specific resistance and temperature coefficient.

Examination of 126 samples of insulating materials with an electric pressure up to 800 volts.

Verification of single resistances, 123 samples.

Calibration of 33 resistance boxes, compensation apparatus, etc., containing 1,153 single resistances.

Comparison and verification of 133 standard cells—111 Clark and 22 Weston elements.

Determination of the ratio Clark 15° C. to cadmium 20° C., and Clark 0° C. to cadmium 20° C., with a large number of standard cells.

Examination of 21 samples of dry and storage cells.

Calibration of 15 galvanometers to measure high and low temperatures with thermal elements.

Magnetic examination of 25 samples of iron and steel.

Investigation of the difference between the continuous and the discontinuous magnetization of steel.

Investigation of the influence of repeated heating on the magnetic hardness of iron.

III. *Work relating to heat and measurement of pressure.*—Calibration of 18,777 thermometers.

Examination of 4 safety appliances and benzine lamps.

Calibration of 317 thermal elements.

Verification of 9 manometers and 22 barometers.

Testing of 190 samples of apparatus for petroleum investigations.

Testing of 3,210 samples of safety rings and plugs.

Testing of 22 samples of indicator springs.

IV. *Work in light.*—Testing of 149 Hefner lamps for photometric purposes.

Testing of 189 incandescent lamps.

Testing of 143 gas and other lamps and adjunct appliances.

Investigation of the relation between the temperature of sugar solutions and their rotatory power on polarized light.

Investigation of quartz plates for the examination of sugars.

Determination of 100 points in the normal Ventzke scale for sodium light.

Especially careful collection of sugars from Germany, Austria, France, Russia, and North America for the investigation of specific rotatory power.

V. *Work in chemistry.*—Continuation of the study of the solubility of important salts.

Electrolysis of platinic chloride and the migration of the ions.

The quantatitive determination of metallic platinum.

Investigation of liquids for use in thermometers to measure low temperatures.

In addition to the above work attention is drawn to the fact that there are two institutions for calibration and certification of thermometers under the control of the Reichsanstalt, one at Ilmenau and the other at Gehlberg. During the last ten years the institution at Ilmenau has tested in round numbers 350,000 thermometers.

The number of persons employed in the Reichsanstalt the past year was 87.

V. A LESSON FOR US.

If Germany has found it to her scientific and industrial advantage to maintain the Reichsanstalt, and is proud of what it accomplishes, and if Great Britain is so impressed with the success of the institution that she has decided to imitate it, it is surely the part of wisdom for the United States to move in the same direction. It is therefore very gratifying that at the suggestion of Secretary Gage a bill was introduced in the last Congress to establish a national standardizing bureau, and that the Committee on Coinage, Weights, and Measures reported unanimously and strongly in favor of its passage. So great is the importance of this movement from the point of view of science, of national pride, and of the higher interests of industrial pursuits, that the effort so happily begun to secure suitable legislation should be repeated with redoubled force and enthusiasm. Some of the reasons for making this effort one does not need to go far to seek.

In the first place, the scientific interests to be served are certainly as great as in any other country in the world. Science is cultivated here with increasing assiduity and success. We are no longer content to follow in the footsteps of European savants and modestly repeat their investigations. Original work of a high order is now done in many American universities, but the difficulties under which university instructors prosecute research are even greater here than in Germany, and we are still compelled to go to Europe for most of our standards. As a result, inventions of an almost purely scientific character originating here have been carried to perfection in the Reichsanstalt, and Germany gets the larger part of the credit. I need only instance the Weston standard cell, which has been so fully investigated at the Reichsanstalt, and the alloy "manganin," which the same institution employs for its standard resistances after a searching inquiry into its properties. Both of these are the invention of Mr. Edward Weston, one of the past presidents of this institute. So long as there is no authoritative bureau in the United States under Federal control, and presided over by men commanding respect and confidence, we must continue "to utilize the far superior standardizing facilities of other governments." It is true that science knows no nationality, but the scientific workers of any nation can serve their own country better if they are not compelled to obtain their standards and their best instruments from distant parts of the globe. America has the cultivation in physical science, the ability on the part of her investigators, and the inventive faculty to do work in a national institution that we shall not be ashamed to place by the side of Germany's best products. The establishment of a national institution for physical and technical purposes can not fail to foster a vigorous and healthy growth in science, to which we already owe so much of our national prosperity and renown.

In the second place Congress should be stimulated to take action because of national pride. It is not creditable for a capable and self-reliant nation to continue to depend on foreign countries for its standards of measurement, for the certification of its instruments, and for the calibration of its normal apparatus for precise work. Different departments of our Government and offices under its control must at present appeal to foreign bureaus for the certification of their standards and instruments of precision. The first day the writer spent at the Reichsanstalt he was consulted with reference to an extended correspondence between the director of the technical division and the officials of the Brooklyn Navy-Yard relative to the calibration of a large number of incandescent electric lamps for use in our Navy Department. The spectacle of a Government bureau going to a foreign imperial institution for standards in an industry whose home is in the United States is a humilitating one. Yet the proceeding was entirely proper and justifiable, because there is in this country no standardizing bureau for the purpose desired. Are the representatives of the American people willing to have this state of affairs continue?

Again, the higher interests of the industrial utilization of scientific knowledge require the establishment in Washington of an institution similar to the Reichsanstalt and in no degree inferior to it. We are an inventive people and may justly claim renown in the prompt and efficient utilization of the discoveries in physical science. It is highly improbable that a practical limit has already been reached in the field of applied physics. We are not estopped from making further discoveries. Still it may be affirmed with confidence that the most important and promising work to be done, except in rare instances in which genius makes a brilliant discovery, will consist in the more perfect adaptation of known physical laws to the production of useful results. It is precisely this field which has not been extensively cultivated as yet in the United States. We have explored the surface and presumably gathered the largest nuggets and the most brilliant gems. To increase the output we must now delve deeper and scrutinize more closely. To drop the metaphor, what will be required for future preeminence is the more intensive and exhaustive study of the scientific conditions in the industrial utilization of physical laws. This study will require the best talent of our technical schools, aided and supported by an authoritative national institution, itself far removed from patents and commercial gains, but jealous of our national renown and eager to cooperate with manufacturers for the sake of national prosperity.

Germany is rapidly moving toward industrial supremacy in Europe. One of the most potent factors in this notable advance is the perfected alliance between science and commerce existing in Germany. Science has come to be regarded there as a commercial factor. If England is losing her supremacy in manufactures and in commerce, as many claim, it is because of English conservatism and the failure to utilize to the fullest extent the lessons taught by science; while Germany, once the country of dreamers and theorists, has now become eminently practical. Science there no longer seeks court and cloister, but is in open alliance with commerce and industry. This is substantially the view taken by Sir Charles Oppenheimer, British consul-general at Frankfort, in a recent review of the status and prospects of the German Empire.

The Reichsanstalt is the top stone of Germany's scientific edifice. It has also contributed much to her industrial renown. It is necessary to cite only her manufactures involving high temperatures, such as the porcelain industry, to appreciate the help afforded by the Reichsanstalt. The methods and instruments elaborated there for the exact measurement of high temperatures constitute a splendid contribution toward industrial supremacy in those lines. The German Government sees with great clearness that the Reichsanstalt justifies the expenditure made for its maintenance, not by the fees received for certifications and calibrations, but by the support it gives to the higher industries requiring the application of the greatest intelligence. In this connection it should be thankfully acknowledged that the services of this imperial establishment are placed at the disposal of foreign institutions of learning with the most generous liberality. The charges for calibration are only about one-fourth the expense incurred in making them, but the support thus given to German makers of instruments of precision, by increasing their foreign orders, is deemed a sufficient return for the services rendered.

FIG. 1.—THE PRESIDENT'S HOUSE.

FIG. 2.—BUILDING FOR LARGE CURRENT AND MACHINERY.

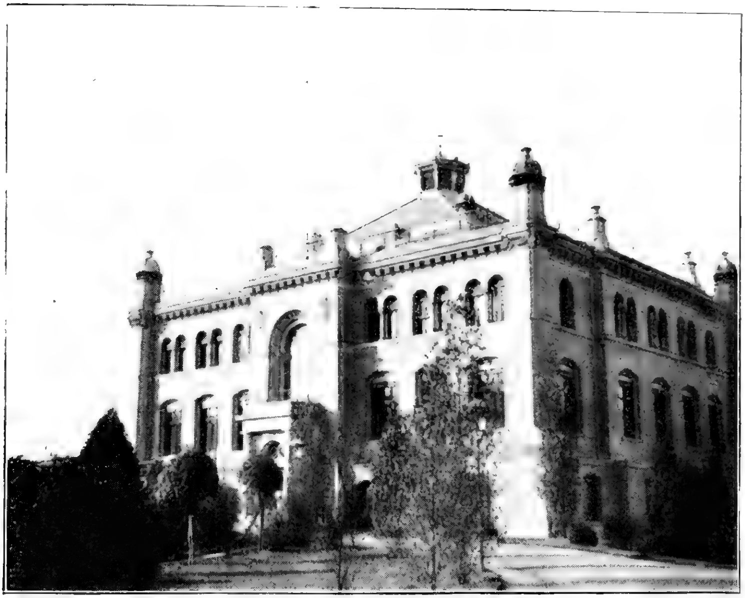


FIG. 3.—MAIN BUILDING, DIVISION I.

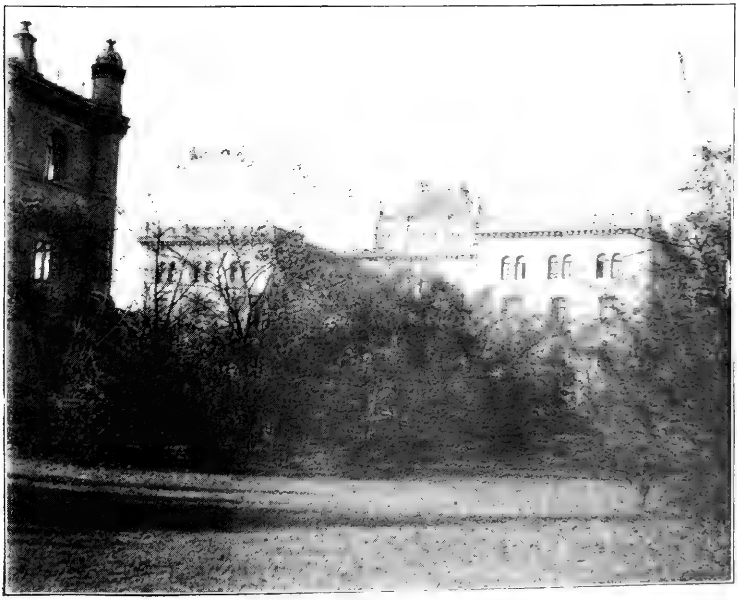


FIG. 4.—MAIN BUILDING, DIVISION II.

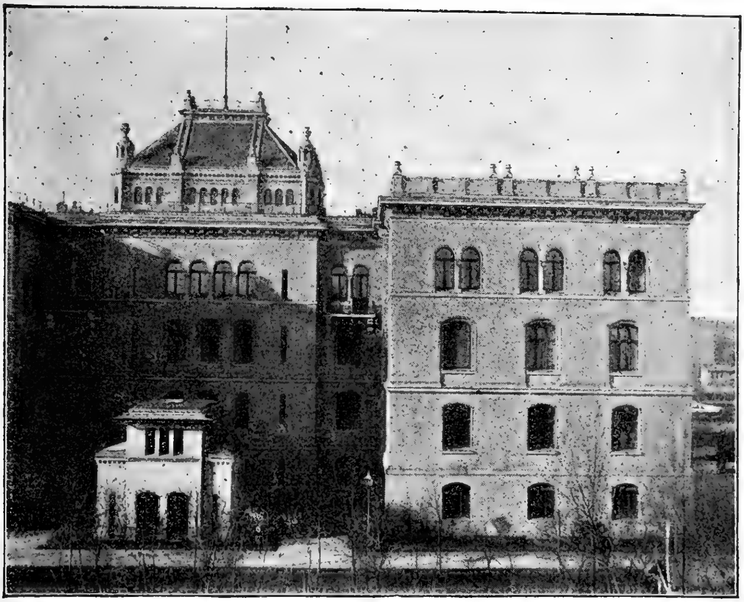


FIG. 5.—MAIN BUILDING (IN PART).

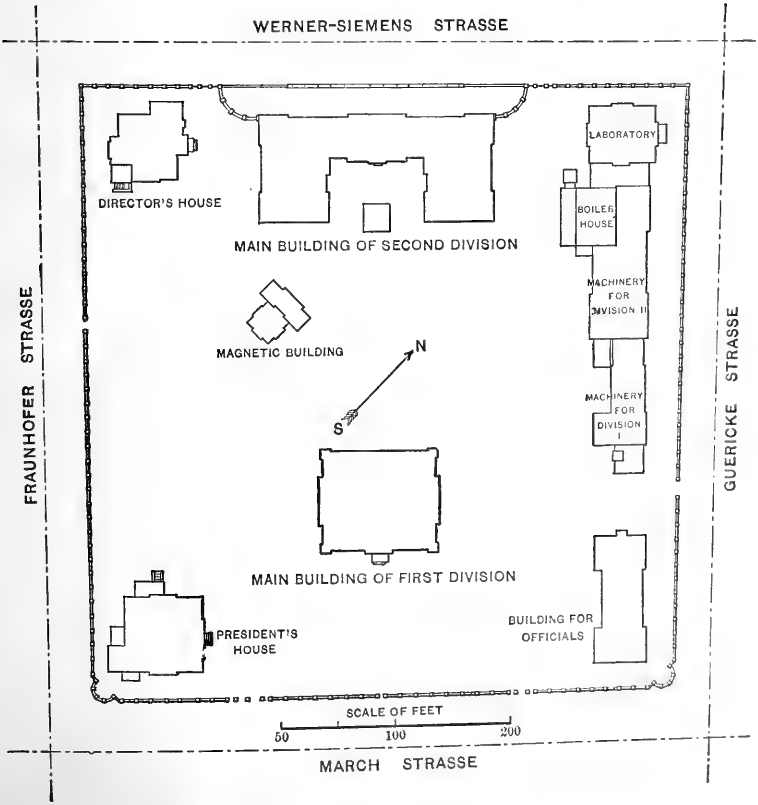


FIG. 6.—GENERAL PLAN OF GROUND AND BUILDINGS.

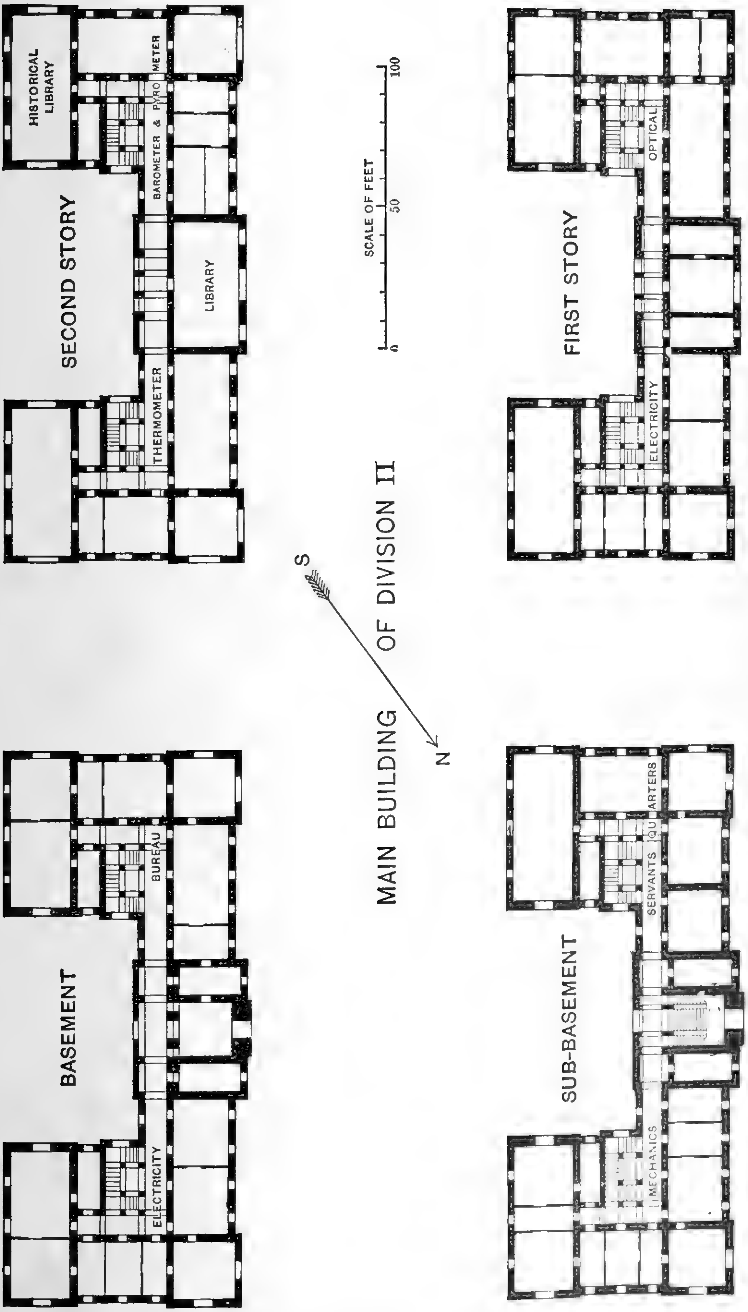


FIG. 7.—FLOOR PLANS OF MAIN BUILDING, DIVISION II.

THE GEOGRAPHIC CONQUESTS OF THE NINETEENTH CENTURY.

By Gilbert H. Grosvenor.

In 1800, the year that Jefferson was first elected President of the United States and Napoleon won the history-making battle of Marengo, about one-fifth of the earth's land surface was known. The physical features of the remaining four-fifths were partly supplied by imaginative map makers or left a blank on the charts given to the public. In 1900 approximately ten-elevenths of the earth's land surface may be described as known and only one-eleventh as unexplored. In fact much less than one-eleventh remains unknown, for the unknown area is so distributed in both hemispheres that nowhere except at the North and South poles are there remaining large unexplored tracts. This will be readily seen by a glance at the maps that accompany this paper.

The eighteenth century had been noted for the explorers of the seas, the nineteenth was preeminent in men who split open great continents and laid bare to the eyes of mankind their mountains, rivers, and lakes.

AFRICA.

One hundred years ago Africa was a gigantic black plate with a white rim which had been tolerably well traced by Vasco de Gama, and other bold Portuguese adventurers of the sea. Though nearer to Europe than any of the continents, stretching as it does parallel to the south coast of Europe for 1,000 miles, the deadliness of its climate had averted the greedy eyes and hands of Spain, France, England, and Portugal, who were battling for dominions in the Americas and India thousands of miles farther away. They came to Africa for slaves to develop the new world and that was all they sought in the Dark Continent.

To-day hundreds of sharply defined lines of light, the routes of the patient Livingstone, of grim Stanley, of Baker, Speke, and Mungo Park, like the piercing beams of a searchlight have penetrated the continent from north and south, from east and west, until there remain black patches only here and there, and these are partly lighted by the rays radiating from the main lines of exploration. Every square mile of this great continent, excepting Morocco and Abyssinia, has, moreover, been peacefully parceled out within the nineteenth century to the powers of Europe, while the possession of India and the Americas cost thousands and tens of thousands of lives lost in battle.

The history of the exploration of Africa centers in the discovery of the sources of the four great rivers of the continent, the Niger, the Zambezi, the Nile, and the Kongo.

In a mighty torrent they swept into the Atlantic and Indian oceans on the west and east and into the Mediterranean on the north, but of the four, the Nile only was known for any considerable distance. Bruce, in the last half of the eighteenth century, had penetrated from the Red Sea to the head waters of the Blue Nile in Abyssinia and had followed the latter to its junction with the Nile near Berber, and then down the Nile to Cairo; but he had not solved the secret of that overflowing stream whose waters had for thousands and thousands of years made the valley of Egypt the granary and garden of the world.

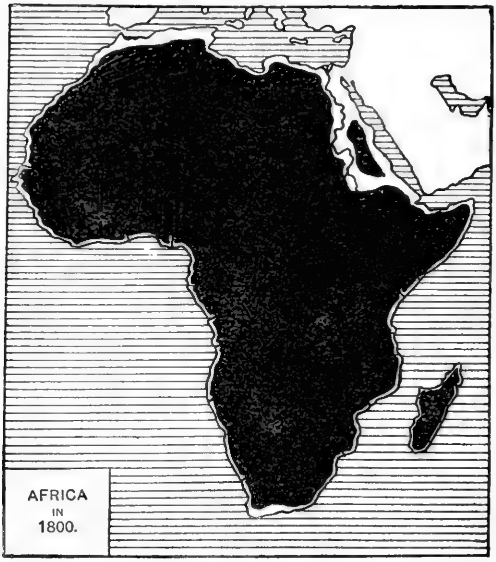


FIG. 1.—Africa as known in 1800. The darkened portions in this and succeeding maps show the unexplored areas.

To-day the Nile has been scientifically explored for its entire length of 3,400 miles; the Niger, with the exception of a small portion of its middle course, for 2,600 miles; the Zambezi, for 1,500 miles; and the Kongo, which in volume is exceeded only by the Amazon, for nearly 3,000 miles.

The course of the Niger was determined early in the nineteenth century and is the record of one man's work and life. Mungo Park, a Scottish surgeon, then but 24 years of age, but already well-known for his discovery of several new fishes in Sumatra, in 1795 undertook to determine for the African Association of London the course of the Niger. Starting from Gambia in December, he reached Segu on the Niger in the summer of 1796, and succeeded in ascending it for several hundred miles as far as Bamaku. Ten years later, 1805, he returned to Bamaku, resolved this time to follow the river which he had been the first to reach, till it entered the sea. For nearly 2,000 miles he hugged its bank in a canoe with four companions and had all but reached its outlet, when his canoe was upset in an attack by the natives at Bussa and he was drowned.

During nearly fifty years after the death of Mungo Park, exploration in Africa was confined to the Great Sahara Desert. Denham and Clapperton in 1822–1824 pushed southward from Fezzan through the burning sands and discovered Lake Tchad, then to Bornu, and thence to Sokoto on the Niger. Several years later Clapperton ascended the Niger from its mouth to Sokoto, where he died.

Another crossing of the desert was made by a brilliant young Frenchman, Caillié, who succeeded in reaching Timbuktu, the mysterious African capital, in 1828. Nearly thirty years later Barth connected the routes of Caillié and Denham, and in 1867–1874 Nachtigal proceeded from the Niger to Lake Tchad, then eastward through Wadai and Darfur to Egyptian Sudan. Binger, Foureau and Lamy, and numerous explorers of later years, have done important work in erasing the blanks between the routes of these great pioneers, while Rohlfs, farther north, explored southern Algeria, Fezzan, and the edge of the Libyan Desert.

The patient, persevering work of Livingstone made possible the opening up of the southern half of the continent. For thirty-three years he toiled in the fearful heat of the Tropics, pausing only for two brief visits to England. Often he was without money and encouragement, dependent upon his scanty means and unfailing courage for the fulfillment of his broad plans. His genius laid the foundations upon which Stanley and the explorers who followed him have worked.

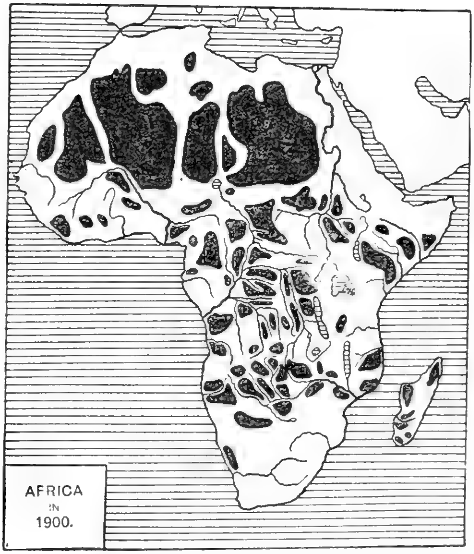


FIG. 2.—Africa as known in 1900.

Livingstone had come to Africa in 1840 as a medical missionary. For nine years he had been penetrating farther and farther from Cape Colony until in 1849 he was stationed at Bolobeng, 80 miles north of Mafeking and 1,100 from Cape Colony. The chief of the people among whom he was laboring told him of a lake to the north beyond the Kalahari Desert and of a powerful chief who ruled over many tribes. Livingstone, animated with the sole purpose of extending his religion, determined to search for the chief and the lake.

On June 1 he set out, and after two months reached Lake Ngami which he found set in the midst of a luxurious, densely populated country. He was not able, however, to advance farther and thus returned to his station without seeing the chief.

Two years later he renewed his effort, passed Lake Ngami, and finally reached the Upper Zambezi at a place called Sesheke, over 1,000 miles from its outlet. Livingstone was a Scotsman and had never seen a real river before, and we can imagine what an effect this mighty stream, discovered 1,000 miles from the coast, and whose origin or outlet he knew not, must have had upon him.

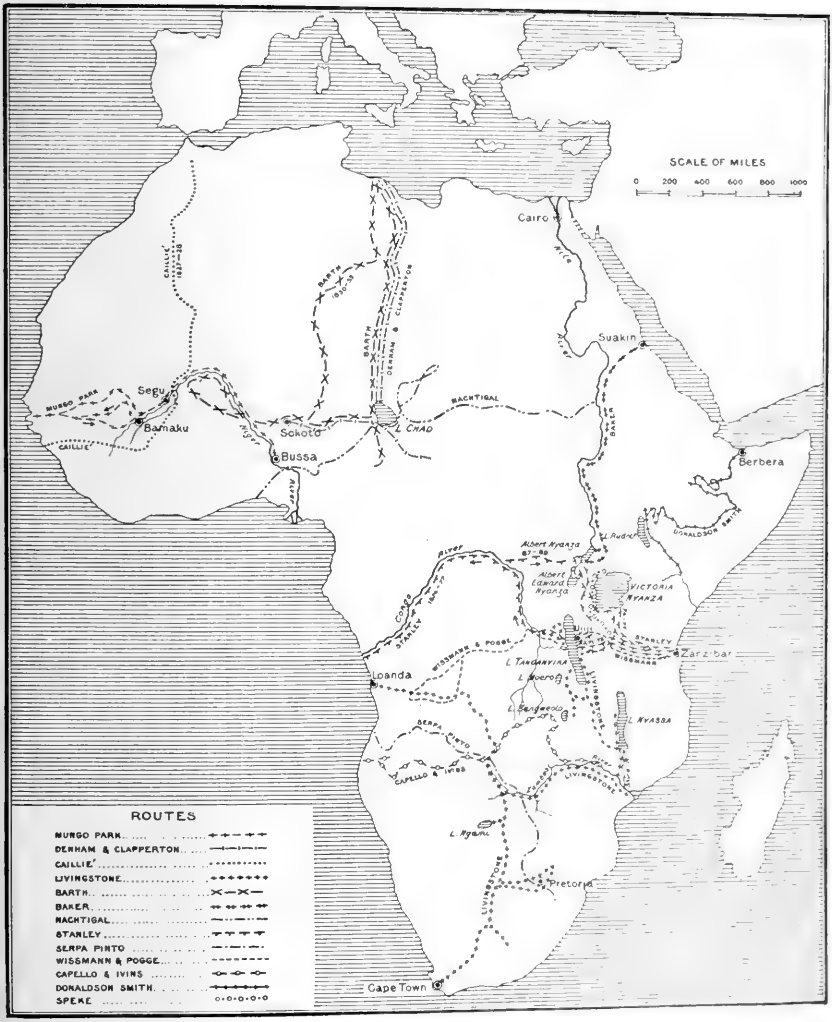
He was now 750 miles from his mission post, and through his entire march he had been continually discovering lakes, rivers, and largely populated towns whose existence had previously been unsuspected. It came upon him that his true mission was to open up Africa, and he therefore returned to the Cape to prepare himself for the work.

In the summer of 1852 he retraced his route to the Upper Zambezi and followed its basin westward for some distance and then pushed farther west until he finally reached the Atlantic Ocean at St. Paul de Loanda. He then returned to the basin of the Zambezi. In all his travels Livingstone never named any lake, river, or mountain that he discovered, but he had not descended the Zambezi many miles before he came upon a grand fall whose waters were dashed upon the rocks 300 feet below. A loyal subject, he named the falls after his Queen, "Victoria." He finally reached the Indian Ocean at Quilimane, thus being the first white man to cross the continent.

In 1858 he began his second great exploration, which resulted in tracing the course of the Shire River, a tributary of the Zambezi, and the discovery of Lakes Nyassa and Shira, feed lakes of the Zambezi.

The problems of the Niger and Zambezi had thus been solved, but the Nile and Kongo still remained a mystery. In 1859 Captains Burton and Speke started from Zanzibar to discover a lake of which rumors had for a long time been heard, and in a few months succeeded in reaching Lake Tanganyika. Returning to the coast they separated, Burton taking a southerly route and Speke a more northerly one. Speke beheld in the far distance another great lake, the Victoria Nyanza, and in 1861 returned with Grant to explore it. On circling the lake they found a large river leading to the north, which they followed for some distance, when they came upon Baker (afterwards Sir Samuel), who had been following it, the White Nile, from Khartum. Baker later continued his search westward and discovered a smaller lake which he called "Albert Nyanza." Thus, by the discovery of Lakes Victoria Nyanza and Albert Nyanza the feed lakes of the Nile were definitely determined.

In 1865 Livingstone set out for the region of Lake Tanganyika and discovered Lakes Moero and Bangweolo, and explored the Luapula



MAP OF AFRICA, SHOWING MAIN ROUTES OF EXPLORATION.

River, which flows from Lake Moero and is the main head stream of the Kongo, though he did not know it, but probably suspected it.

The world became alarmed at not hearing from him for some time, and Stanley was dispatched to find him by James Gordon Bennett, of the *New York Herald*.

Stanley cut across from Zanzibar and found him at Ujiji, on Lake Tanganyika. He had been surrounded by Arab slavers, his supplies destroyed, and his communication with the seacoast interrupted. After being relieved by Stanley, Livingstone returned to Lake Bangweolo, where he died in 1873. His faithful followers bore his body to the seacoast and later it was carried to England and buried in Westminster Abbey.

Stanley took up the work of Livingstone. After circling Victoria Nyanza, he explored Albert Nyanza and Tanganyika and discovered Albert Edward Nyanza. He then descended the Lualaba Basin, which brought him to the Kongo, which he followed to the ocean.

Stanley was thus able to solve the last great African problem, namely, that Tanganyika and the waters west of it belonged to the basin of the Kongo and not to the Nile.

But of more practical value than the determination of the question of the head waters of this river was the opening up to the commerce of the world of the densely populated countries along the banks of the Kongo and its tributaries.

In 1887 Stanley started to cross Africa again, this time from west to east, to relieve Emin Pasha. After leaving the Kongo he forced his way through a vast, almost impenetrable forest, and saw the pigmies, discovered by Du Chaillu twenty-five years before, and the Mountains of the Moon.

In this brief summary it is possible to mention only a few of the dauntless explorers who before and since the time of Livingstone and Stanley have helped to render obsolete the term of "Dark Continent"—the imaginative Du Chaillu, the botanist Schweinfurt; the gallant Cameron, who was the first to cross Africa from east to west (1873–1875); Serpa Pinto, the Portuguese political explorer; Wissmann, who discovered the left affluents of the Kongo, and Donaldson Smith, who traced Lake Rudolf in 1894–95 and in 1900 crossed the country between that lake and the Nile, the last inhabited area of importance that was unexplored.

The feat of young Grogan, who traversed the continent from the Cape to Cairo, during the greater part of the way without a white companion, was a fitting conclusion to African exploration of the nineteenth century.

THE ARCTICS.

Three long-sought ambitions inspired the efforts of the Arctic explorers of the nineteenth century—first, to discover a Northwest Passage to India; second, to discover a Northeast Passage, and, third, to reach the North Pole.

The first two objects were attained. McClure, in 1850–1853, forced a painful passage from Bering Strait to Europe, and nearly thirty years later Baron Nordenskjold, the Swedish scientist, succeeded in reaching the Pacific Ocean by following the Asiatic coast. Neither of these routes have yet proved of practical value to the world. With the development, however, of northern Siberia, in view of the possibility of the route being kept open by vessels of the type of the ice-breaking *Yermak*, the Northeast Passage may become a route of some traffic in lumber, furs, etc.

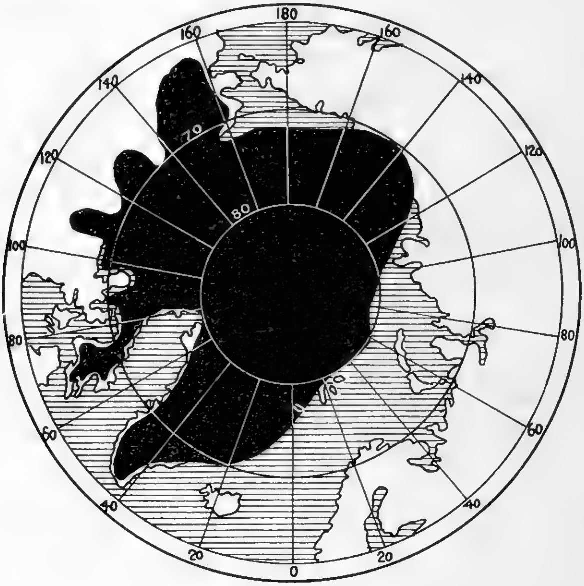


FIG. 3.—Arctic Regions as known in 1800.

The North Pole remains still unconquered, though it is not so remote. Hall, Lockwood, Nansen, and Abruzzi have each gone farther than his predecessor, until only 3 degrees and 27 minutes have to be overcome.

In 1800 the Arctic coast of North America was undetermined. Mackenzie, in 1789, had descended to the mouth of the river which bears his name, and some years before him, in 1771, Hearne had descended the Coppermine to its mouth. Both reported an open sea to the north. On the Asiatic coast, the outlets of the Lena, Yenisei, and Obi were known, the Bear Islands had been visited, and Nova Zembla discovered centuries before.

Parry, Beechey, Franklin, and Richardson, during the earlier years of the century, helped to define the North American coast, and Scoresby outlined the east coast of Greenland. James Ross, in 1830, definitely located the North Magnetic Pole at Cape Adelaide, in Boothia Felix, and three years later Back discovered the Great Fish River.

Of the many tragedies in the annals of Arctic history, none is more terrible and heart-rending than that of Sir John Franklin and his crew of one hundred and twenty-nine. The *Erebus* and the *Terror*, returned from the Antarctics, where they had carried Sir James Ross to splendid achievements, were placed at the disposal of Franklin, who had been knighted for his gallant work in the Arctic regions in his earlier years. He set out in May, 1845, and was last spoken by a whaler while he was waiting for the ice to open sufficiently to enter Lancaster Strait. The following year and the year after, his vessels were beset by the ice near King William Land. Franklin died in June, 1847. The crew had provisions only for one year longer, and as the vessels were still icebound the one hundred and five survivors left their ships in a desperate and vain attempt to fight their way over the ice to Great Fish River. During 1848 and for many succeeding years expeditions were dispatched both by land and sea from the east, west, and south to search for the missing men, but it was not until 1854 that Rae met a young Eskimo who told him that four years previously forty white men had been seen dragging a boat to the south on the west shore of King William Land, and a few months later he had found the bodies of thirty of these men.

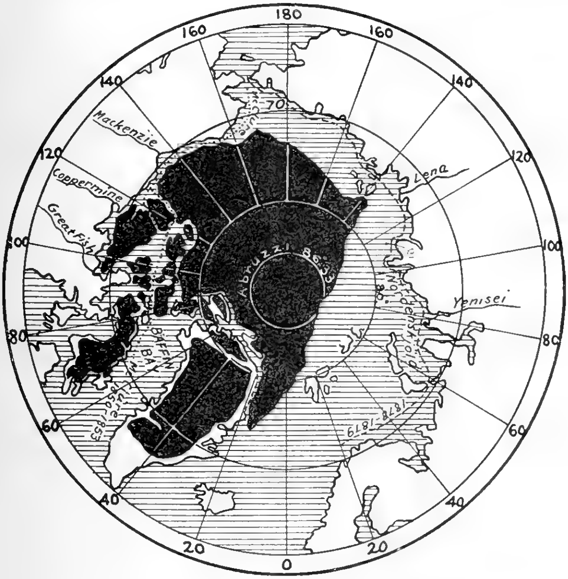


FIG. 4.—Arctic Regions as known in 1900.

McClure and Collinson were sent out in 1850 to attempt the search from the west through Bering Strait. McClure started without waiting for Collinson. He gradually worked his way eastward, winding back and forth through inlets and around headlands and islands, many of which he was the first to discover, and at last emerged through McClures Strait into Barrow Strait. Finally, in Baffins Bay, he was compelled to abandon his ship, the *Investigator*, and push on over the ice. Fortunately he was met by a Franklin search expedition coming from the east, under Sir Edward Belcher. By his feat, the first completion of the Northwest Passage, McClure gained the prize of $50,000 that had been offered by Parliament ninety-two years before.

Nine years of unceasing effort had failed to find any record of Franklin's terrible fate. But Lady Franklin was still undaunted. In 1857 she equipped the steam yacht *Fox* and sent it to the Arctics, commanded by McClintock, the most untiring master of sledge work. Eight hundred miles of coast line were minutely examined. In the early summer of 1859 McClintock stumbled upon a human skeleton in King William Land, and about the same time his companion, Hobson, found a record of the Franklin expedition, stating briefly its history between 1845 and 1848.

The result of the many Franklin search expeditions was the mapping more or less accurately of the network of islands extending along the northern coast of North America.

Meanwhile Kane, Hall, and Nares were completing the surveys of Smith Sound, Grinnell Land, and the adjacent shores of Greenland. The Greely expedition proved that to the north of Greenland was an open channel and gained what is still most northerly land, 83° 24′. Later Peary followed this channel in his brilliant crossing of North Greenland, and proved conclusively that Greenland was an island.

Nordenskjold had already spent twenty years adding to the maps of Greenland, Spitzbergen, and the Kara Sea, when, in 1878, he determined to reach Bering Strait by crawling around the headlands and islands of Northern Asia. Without any hindrance he had arrived almost in sight of Bering Strait when the tantalizing ice closed in before him and for ten months his ship was held motionless. Then the ice mass deigned to part and allow the *Vega* to sail the few remaining miles to and through the strait, and thus complete the Northeast Passage.

Franz Josef Land, which has lately been a favorite base in the "dash for the pole," was discovered and explored by Payer and Weyprecht in 1872–73; later Jackson, 1895–96, Baldwin, 1899, and Abruzzi, 1900, have extended our knowledge of this region and shown that beyond the islands is an ice-covered sea.

In the early nineties Dr. Nansen originated a new method of attack of the North Pole, "the drift theory." His experiment of allowing his ship, which was specially constructed to elude rather than to resist ice pressure, to be carried at the will of the ice floes, proved very successful, and he gained latitude 86° 14′, which was only eclipsed by Abruzzi in 1900.

ANTARCTICS.

Around the South Pole there hangs an unexplored mass twice the size of Europe. It may be a vast continent or an antarctic ocean: the problem is yet unsolved.

The names that shine brightly in the history of South Polar work during the century began with Captain Smith, who discovered the South Shetland Islands in 1816. Weddell, several years later, found an active volcano on these islands and reached as far south as 74 degrees, but discovered there no land. Enderby Land and Graham Land were seen first by Biscoe in 1832. Wilkes in 1840 discovered the land named after him, and Sir James Ross, of previous Arctic fame, about the same time discovered Victoria Land, and upon it beheld two active volcanoes pouring forth flaming lava amidst the snow, and named them Erebus and Terror, after his two ships. In January, 1842, he reached farthest south—78 degrees—a record that was not eclipsed until 1899, when Borchgrevink reached 78° 50′ by sledge.

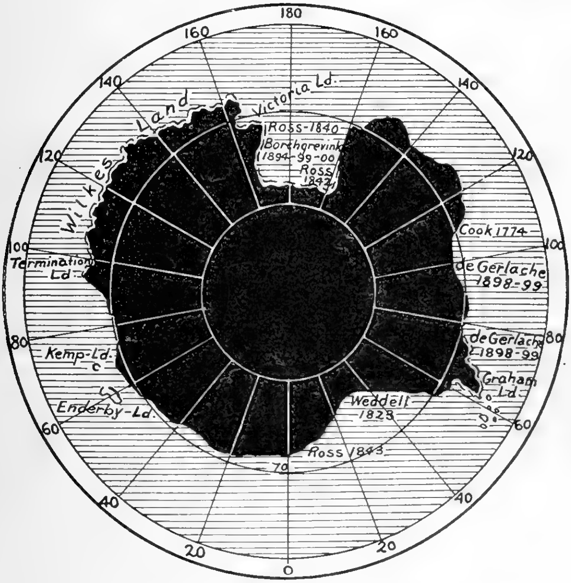


FIG. 5.—Antarctic Regions as known in 1900.

No white men had ever passed the winter within the Antarctic Circle until De Gerlache and his crew in 1898 wintered on board their ship, the *Belgica*, which they had banked with snow. The following winter Borchgrevink with his crew lived on the antarctic ice.

The closing year of the nineteenth century witnessed the near completion of two well-equipped expeditions that are to set out in the summer of 1901 for South Polar regions—one equipped by Germany and the other by Great Britain. Both are led by competent and daring men, and great additions to our knowledge of the Antarctics may be justly expected.

AUSTRALIA.

The last months of the nineteenth century beheld the beginning of a new power in the South Pacific. Six millions of Englishmen, in a land as vast as the United States, united to form a new nation, which the twentieth century was to inaugurate. The first year of the nineteenth century found Australia inhabited by degenerate savages, with a handful of English settlers scattered along the coast of what is now called New South Wales. The coast line of Eastern Australia had been definitely traced and enough facts of the north and west coasts ascertained for a rough outline of their extent, but the south coast was undetermined and absolutely nothing was known of the interior. Port Phillip, the magnificent harbor on which gaze the half a million inhabitants of Melbourne, the wealthiest city in the Southern Hemisphere, had been entered by no European ship. The immense lifeless mass had no name of its own, but appeared on the maps as New Holland.

Fig. 6.—Australia as known in 1800.

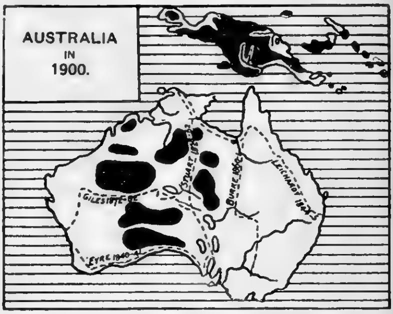


Fig. 7.—Australia as known in 1900.

Captain King early in the century investigated the river mouths and completed the shore line for the west, northwest, and north coast. Sturt in 1828 and succeeding years explored New South Wales and penetrated to the center of the continent. Eyre in 1840 traced the south coast along the Great Australian Bight. The first crossing of the continent was made by Stuart in 1862. He passed through the center of Australia and planned the route which the transcontinental telegraph now follows. Colonel Warburton in 1873–74, starting from the central point of the telegraph line, succeeded in reaching the west coast, and later Giles and Forest explored the country to the southwest.

Leichardt successfully crossed Australia diagonally from Port Essington to Moreton Bay, but on his second expedition, in 1848, he mysteriously disappeared in the sandy deserts of the northeast and numerous search parties have failed to find any trace of him.

Overland routes have now been found possible between all the widely separated colonies, though they are scarcely convenient for traffic. The explorations of more recent years have shown that wide areas of splendid grazing land surround the deserts.

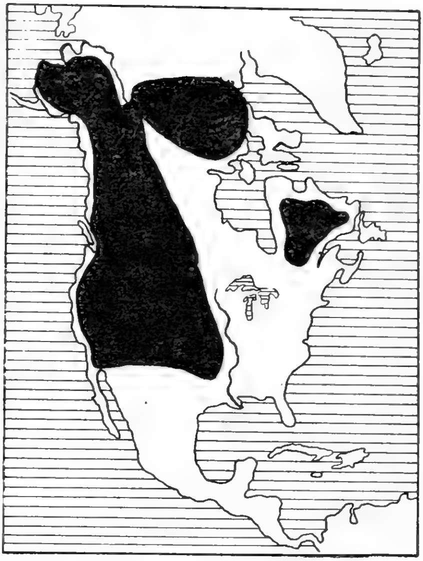


FIG. 8.—North America as known in 1800.

NORTH AMERICA.

Of the geographical conquests of the nineteenth century the most marvelous has been the conquest of North America, more particularly of the western United States. It has been the work not so much of the geographer or explorer, as of the colonist and the miner, made possible by Yankee inventions that economize space, time, and money.

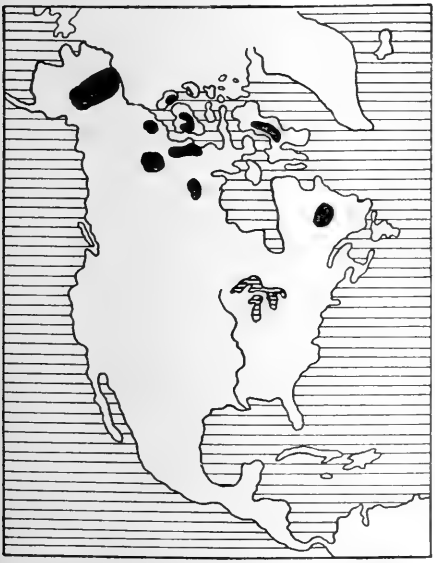


FIG. 9.—North America as known in 1900.

In 1801 the continent west of the Mississippi was unknown, the existence of the Rocky Mountains unsuspected. The atlases of the time describe North America as "chiefly composed of gentle ascents or level plains." They knew of "no considerable mountains except those toward the Pole and that long ridge which runs through the American States and is called the Appalachian or Alleghany Mountains." Immediately after the Louisiana Purchase Lewis and Clarke were dispatched to the new land to explore it, and they made their historic march up the valley of the Missouri River, across the Rocky Mountains, and down the Columbia to the sea. Pike, the year following, commenced his explorations of the country between the Mississippi and the Red River and discovered Pikes Peak in 1806. Bonneville, in 1831–1838, explored sections of the Rocky Mountains and California. Fremont, the most noted of American pioneers in the West, in 1842 explored the South Pass of the Rocky Mountains and in the following years the Pacific slope. Powell, in 1869, traversed the noble and menacing gorges of the Grand Canyon of the Colorado. Meanwhile Whitney, Wheeler, and Hayden were investigating the mountain systems of the West.

In Alaska, Dall was the pioneer and his work revealed the extent of the Yukon. Kotzebue, the Russian navigator, fifty years before, in 1816, had coasted along the northwest coast of Alaska and discovered the magnificent sound which now bears his name. Schwatka, Allen, Abercrombie, Brooks, and Schrader, and others, including gold prospectors, have explored the territory very rapidly until only a few tracks remain unknown. In Canada, Dawson and Ogilvie have worked in the Yukon watershed; Bell and the Tyrrell brothers around Hudson Bay, and Low in Labrador.

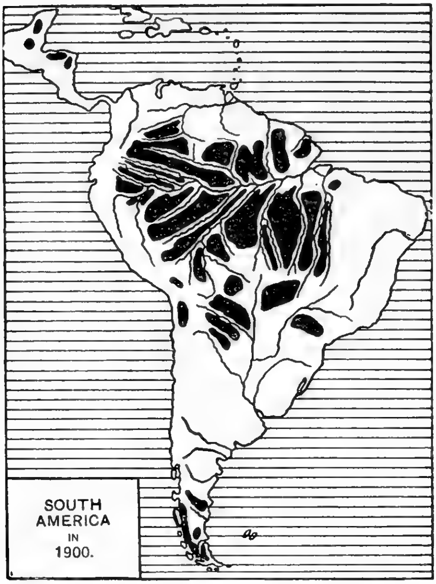


FIG. 10.—South America as known in 1900.

SOUTH AMERICA.

Of the six continents South America is now the least known, though one hundred years ago it was better explored than any continent except Europe. The Jesuits had penetrated to the heart of the continent on the rivers which radiate in all directions and had been able to publish tolerably good maps. But the continual state of unrest and the depleted treasuries of the South American governments, with the lack of the incentive of trade and colonization, have kept them from keeping pace with the geographic advance in other sections of the world.

Humboldt, in 1799–1804, traveled in the basins of the Orinoco and Magdalena and in various sections of the Andes. He was the first to interpret the word "geography" in its original, truest, and broadest sense, i. e., "description of the earth," which includes meteorology, climatology, the distribution of animals and plants, and the nature of soils, as well as the mere mapping of rivers and mountains. Later his interpretation of the work of the geographer and explorer was accepted by all the scientific explorers of the nineteenth century. Later, Spix and Martius botanized in Brazil, Schomburgk explored British Guiana, Crevaux and Chandless investigated the mighty tributaries of the Amazon, Castelnau explored the Paraguay, and Hatcher, in 1898, made important discoveries in Patagonia.

ASIA.

Marco Polo was the only European who before 1800 had traversed any considerable part of Asia. But during the nineteenth century the continent was overrun by explorers of every nationality, who have made the map of the continent in the larger details quite accurate. Russia from the northeast sent numberless explorers, and England vied with her from the south. In one respect, perhaps, the geographic conquest of Asia has been more remarkable than that of Africa, Australia, or North America, for to penetrate this giant continent the explorer has had to contend against hundreds of millions of people — all prejudiced against his advance and of quite a different character from the naked savages of the "Dark Continent."

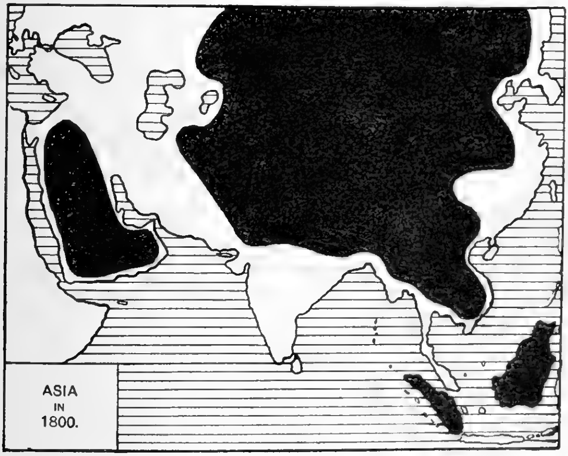


FIG. 11.—Asia as known in 1800.

Humboldt, in 1829, invaded Central Asia and the country of the Caspian Sea. The French missionary, Huc, succeeded in traversing Tibet in 1844–45 and lived several months at Lhasa. Palgrave, in the early sixties, journeyed across Arabia. The adventurous Garnier, in 1866–1868, surveyed the course of the great Mekong and traversed over 5,000 miles in Cambodia and China, almost all of which was previously unknown to European geographers. Ney Elias at the same time was ascending the mighty Yangtze and penetrating western Mongolia. Fedchenko, in Pamir, and the untiring Prjewalski, in Mongolia and western China, were rapidly mapping these regions.

Prjewalski made four separate journeys to western China, and in the importance and extent of his explorations in the heart of the vast continent has been equaled by none except Sven Hedin. Richthofen and Pumpelly in China, Rockhill in Tibet, Forsyth in East Turkestan, and the faithful, plodding pundits of the trigonometrical survey of India north of the Himalayas, are a few of the many men who have contributed much to the progress of geographic knowledge of Asia.

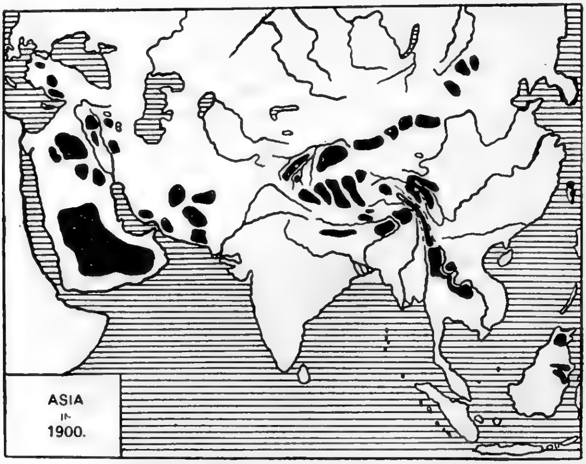


FIG. 12.—Asia as known in 1900.

CONCLUSION.

The progress of geography during the nineteenth century has thus opened to the white man almost every corner in the immense, diverse world of which he is a part. But the even more startling advance in geographic sciences, or, more truly, the creation of these sciences during the century, has nearly explained the manner of origin and the formation of the world itself. Geology, which describes the nature and forming of the earth's crust, tells of glacial action, and by means of fossils proves that the earth millions and millions of years ago was covered with life; meteorology, which studies the conditions governing the heavy and yet light mantle of the earth; oceanography, which is beginning to explore the lands beneath the oceans, are all geographic conquests of the nineteenth century. The "Dark Continent" at the beginning of the twentieth century is that immense land surface buried beneath the oceans, an area thrice the area of the exposed land surface. Maury and Murray and the soundings for submarine cables have but scratched the surface as with a pin. To solve the many mysteries which the oceans hide is the problem of the explorer of the twentieth century.

THROUGH AFRICA FROM THE CAPE TO CAIRO.[1]

By Ewart S. Grogan.

(Read before the Royal Geographical Society, April 30, 1900.)

There is a saying in South Africa that "everyone who has once drunk dop (a brandy made in the Cape) and smoked Transvaal tobacco will, in spite of all inducements to the contrary, in spite of all the abominable discomforts inseparable from life in Africa, continually return to the old free untrammeled life of the veldt."

Anything more ridiculous than the possibility of my return to Africa never occurred to me as I wearily munched my ration of everlasting bully beef and rice during the Matabele war of 1896, and, after three weeks of dysentery and an attack of hæmaglobinuric fever, I shook my fist at Beira from a homeward-bound steamer, happy in the thought that never again should I set eyes on those accursed sands. Thirteen months later I stood on those same sands with my friend, Mr. Sharp, having made up our minds to explore the little-known country between Tanganyika and Ruwenzori, and, if possible, to continue our journey down the Nile. Wars and rumors of wars in many of the countries to be traversed, and Khartoum in the clutch of the Khalifa, rendered the success of our enterprise extremely problematical; and as failure is unpardonable, we wisely refrained from announcing our intentions.

From the Cape to the Zambezi is perhaps better known to most English people than many parts of England, and consequently I will pass over this stage, confining myself to a very few remarks on the Gorongoza country of Portuguese East Africa.

The river Pungwe, as everyone knows, flows into the channel of Mozambique, forming with the river Busi the extensive bay on which Beira, the port of Rhodesia, is situated. Thirty-six miles in a straight line from Beira the railway crosses the Pungwe to a spot called Fontesvilla, on the right bank. Four miles above this the Pungwe flows in two channels; the left, which is the larger, is called the Dingi Dingi, the inclosed island being about 40 miles by 6. Twenty miles above the lower junction an important tributary called the Urema flows into the

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[1] Reprinted from The Geographical Journal, London, Vol. XVI, No. 2, August, 1900.

Dingi Dingi, bringing down the drainage of the east and northeast slopes of Gorongoza's hills and the drainage of the vast swampy Gorongoza plain; consequently, even in the dry season the Urema has a considerable body of water. Its main feeders are a wide sandy river from the east and a smaller stream called the Manza, also from the east, and the Umkulumadzi, which brings the main volume of water from Gorongoza's hills on the west. Between the Dingi Dingi and the Urema there is a triangular patch of forest, with a network of deep water troughs; these, even in Mr. Mahony's time (Mr. Mahony has been in this country for about nine years), were lagoons with much water, and the natives went from village to village in canoes. Now, with the exception of a few deep water holes, they are dry, the canoes may still be seen rotting on the dry bed, and the crocodiles, the few that have survived, lead a precarious existence in the moist grass that grows along some of the deeper channels. This, coupled with the fact that the swamps a few miles to the north are visibly diminishing, proves that even in this district, remote as it is from the center of disturbance, there is a constant and rapid process of upheaval.

The quantity of game in all this country is incredible. Crossing the great plain just as the waters were falling and the new grass growing up, we saw over 40,000 head of game, mainly blue wildebeest, from one point, and during our stay of five months, besides many fine heads of buffalo and various species of antelope, we shot 17 lions and captured alive 5 cubs, 3 of which are now disporting themselves in Regent's Park. Another curious point about this country is that the Urema, which was till lately navigable for about 50 miles in small boats, is now totally blocked by a vegetable growth similar to the famous Nile "sudd," but without the papyrus, which, I believe I am correct in saying, is practically confined to the Nile system, though there are a few papyrus swamps round Kivu.

We began our real forward movement when we left the Zambezi in October, 1898; thence we traveled by the Shire River to Chiromo, the port of British Central Africa, situated at the junction of the Ruo and Shire. Thence by steamer on the Shire to Katunga, whence the road leads overland via Blantyre to Matope, as about 120 miles of rapids render the river unnavigable. From Matope to Karonga, at the north end of Nyasa, there is an uninterrupted waterway of about 500 miles. Thus far, it is merely a question of taking a first-class ticket with one of the rival transport companies, of which the African Flotilla Company, despite the heavy handicap of being late in the field, is rapidly forging to the front.

From Chiromo, where I had to wait for some loads that had gone to Delagoa Bay by mistake, I crossed the Ruo and spent some time in exploring the mountain mass of Chiperoni, while Sharp hurried on to Karonga to arrange transport to Tanganyika.

Chiperoni, which had previously, I believe, only been visited by Messrs. Harrison and Kirby, the well-known big game hunters, is 6,000 feet high, and a conspicuous landmark for many miles round. The main peak, with a broad terrace 500 feet from the summit, is situated in the east side of a huge basin formed by surrounding peaks, the chief of which is Makumbi on the northwest. The bottom of the basin is a forest-clad plateau about 2,000 feet about the surrounding plains. The mass is drained by the Ruo, Liadzi, Zitembi, Machinjiri, and Misongwe, all of which flow into the Shire. The inhabitants, who have a supreme contempt for the Portuguese, their nominal masters, are a branch of the Wakunda, and are possessed of domestic swine and pigeons, and they cultivate the pineapple and rice, besides the ordinary grains of the country—millet and maize. They suffer much from goiter, and I observed many albinos. The results of inbreeding, inevitable from the isolation of families in mountainous countries, such as leprosy and other diseases, are very noticeable.

On arrival at Karonga I found that Sharp had left for Ujiji to obtain dhows on Tanganyika. After a fortnight's delay in obtaining porters I followed along the Stevenson road. The march to Kituta, at the south end of Tanganyika, is most uninteresting. However, I broke the monotony by a short trip with Mr. Palmer, the assistant collector at Mambwe, to the Chambezi, which is the real source of the Kongo. This district has been recently thoroughly explored by Mr. Wallis, who laid the results of his experience before this society. But there was still a portion unknown—the vast swamp that lies at the junction of the Chambezi and its main feeder, the Chosi, known to the natives as Luwala. It is a triangular patch of territory of about 1,500 square miles and quite uninhabited, a few natives only coming to fish as the waters recede after the rains. Unfortunately, the rains had broken and we were prevented from penetrating far into the interior by the depth of water. All the streams that flow southeast from the plateau and fall into the Luwala mingle and lose themselves in the swamp and eventually drain out by the Mwenda.

From Kituta I went to Mtowa, the chief station of the Kongo Free State on Tanganyika, by the small steamer belonging to the African Lakes Corporation, while I sent my boys and the loads to Ujiji on a dhow that Sharp had sent down. On arrival at Mtowa I found Sharp more dead than alive with fever, in the care of the late Dr. Castellote, the medical officer of Mr. Mohun's telegraph expedition, who had rescued him from Ujiji, where he had been very ill. Two days later we crossed to Ujiji and, after a few days of the lavish hospitality of Hauptmann Bethe and his colleagues, we collected our safari of one hundred and thirty Manyema carriers and started up the lake by land. Sharp got a slight sunstroke and my fever became so bad that we arrived at Usambara more dead than alive. However, Lieutenant von Gravert obtained cattle for us and a team of boys to carry me in a machila to the highlands of Kivu.

The Rusisi, which flows out of Kivu, empties its water into Tanganyika through five mouths, four of which are close together, while the fifth is close to the northwest corner. The inclosed deltas are very swampy and partly covered by tropical forest, and are said to be the feeding grounds of numerous elephants, a large proportion of which are reported as tuskless. The northern end of Tanganyika is very shallow; we saw hippopotami walking on the bottom at a distance of at least 2 miles from the shore. The lower end of the Rusisi Valley for a distance of 20 miles has risen quite recently, geologically speaking, deposits of shells in a semifossilized state being visible on all sides. The valley rises very gradually till 20 miles south of Kivu, when the increase in altitude is very abrupt; though this might be maneuvered, for railway purposes, by making use of the winding valley to the east. The Rusisi itself has cut a channel through the hills on the west in a succession of rapids and cascades. There are signs of the above-mentioned eastern valley having been the old bed of the river. Immense walls of mountains shut the valley in on either side, walls that continue practically unbroken to the outflow of the Nile from the Albert Lake. The Germans have cleverly availed themselves of the opportunity afforded by the five years' chaos on the Belgian frontier. They have pushed three posts forward, two on the river itself and the third on the south point of Lake Kivu. The latter is at least 40 miles over the treaty boundary. With the thoroughness characteristic of German undertakings they have dispatched Dr. Kandt to investigate the possibilities of the country.

The tail of Kivu is a network of islands which culminate toward the north in the large island of Kwijwi. The coast line must be something enormous, rivaling, I imagine, the coast line of any other water in the world of the same extent. On the east coast two long arms run for several miles inland, and thousands of winding lochs radiate in every direction, dotted with islets and broken up into countless little bays and creeks. The lake is very deep and contains neither crocodiles nor hippopotami. This also applies to all the small lakes and rivers in this neighborhood; but there are enormous numbers of large otters, and the typical bird is the demoiselle crane. Numerous fish resembling a carp are caught and cured by the natives; but there appeared to be no large fish such as are found in Tanganyika. The whole surrounding country is packed with small hills, which appear to have been sprinkled on with a pepper pot till not a single one more could find room. The majority of them are not connected with ridges of any sort, consequently it is necessary to perpetually ascend and descend; and the valleys, which are very narrow, are often filled with papyrus swamps.

The hills are covered with magnificent pasture, which affords grazing for the large herds of cattle owned by the Watusi. The people are known collectively as the Waruanda, and society is divided into two classes. The Watusi, who are similar to, if not identical with, the Wahuma, are the aristocrats. They are presumably descendants of the great wave of invasion of Gallas that penetrated in remote ages as far as Tanganyika. They are a purely pastoral folk, breeding a long-horned cattle, with which they live, preferring slavery even to separation from their beloved beasts. Two to a hundred of these gentlemen are to be found in every village; they do not work beyond milking and butter making, and when in need of tobacco, grain, or other necessaries, quietly relieve the aborigines of the country, whom they call Wahutu, of what they require. The Wahutu are abjectly servile to the Watusi, but presumably, from the satisfaction that we gave to the inhabitants by a slight difference of opinion that we had with Ngenzi, the satrap of Mukinyaga, not totally in accord with their taskmasters. In the time of the late King of Ruanda there was a very formidable and far-reaching feudal system, the provinces being administered by satraps (native name, ntwala), who were directly responsible to the kigeri, or king, each village being in itself governed by an mtusi (sultani), who was responsible to his ntwala. All the cattle belongs to the King absolutely, but was held in trust by his satraps, who again parceled it out among the minor Watusi. The Wahutu appear to be merely hewers of wood and drawers of water, and to be allowed as a favor to assist in the herding of the goats and cattle. A few months before our visit the old king had died, and the kingdom was divided between his two sons, one of whom had his headquarters at the northeast corner of the lake, while the other lived to the east of the highest of the volcanoes.

The civilizing influence of the northern influx is conspicuous in the terracing of the hills for cultivation, rudimentary efforts at irrigation, inclosing of villages and cultivated lands by hedges, and even in the formation of artificial reservoirs with side troughs for watering cattle. The scenery of Kivu is superb—a happy blend of Scotland, Japan, and the South Sea Islands. The track we followed often led over hills 1,500 feet above the lake, and from some of our camps we looked down on the vast oily expanse of water deep set in its basin of innumerable hills, dotted with a thousand isles, stretching far away till it was lost in the shimmering haze of the northern shore, where crisp and clear towered the mighty mass of Kirunga, whose jet of smoke alone broke the steel-blue dome of sky. At the northeast corner of the lake the hills stop, and the country slopes gradually from the lake level to the base of the volcanoes, broken only by scattered dead volcanic cones still perfect in form. The eastern portion of this plain is densely populated, and grows enormous crops of maize, hungry rice, millet, sweet potatoes, pease, beans, and edible arum wherever there is an open space between the endless banana plantations. The western portion, which has been recently covered by a lava stream, is not yet sufficiently disintegrated for cultivation, though it already supports a heavy bush growth which bursts from every crack and cranny in the lava blocks.

The main volcanoes are six in number, two of which are active; the other four have long been extinct. Owing to the impossibility of obtaining representative names for them—I have obtained as many as thirty-six for the highest in one camp—I have ventured to name the most important to prevent confusion. Of the two western peaks, which are sharply separated from the other four, the higher peak, generally described as Kirunga, I have called Mount Götzen, after Count Götzen, who discovered Kivu and made the ascent of the peak to the main crater, which is still mildly active. The second one, which has formed since Count Götzen's visit, I have called Mount Sharp, after my fellow-traveller, Mr. A. H. Sharp. Count Götzen mentions considerable activity on the far point of the northwestern ridge, and, according to the natives, two years before our arrival in the country there had been a terrific eruption, in the course of which the volcano formed; its crater appears to be enormous, and must be several miles in extent. The lava flowed in two main streams toward the north, and there was a minor overflow to the southwest. The largest stream flowed down by the arête between Mounts Götzen and Sharp, and a small overflow running, as I have mentioned, southwest, while the main volume poured down into the south end of the Ruchuru Valley, down which it flowed for a distance of about 30 miles, working close up to and filling the small bays of the eastern terrace. Shortly after another wave followed over the same course, leaving a sharply defined terrace when it cooled. Then there appears to have been a terrific vomiting forth of huge blocks of lava and ash, which in places are piled to a height of 30 feet on the top of the main lava stream. The forest with which the valley was clothed was entirely engulfed in the stream's course, while the forest on the sides was blown down by the attendant whirlwinds. The natives informed me that whole herds of elephants were destroyed. I myself saw the bones of one that had been forced up to the top by the edge of the stream. As far as I could gather, the eruption had been very sudden, but I found it extremely difficult to obtain much information beyond the fact that suddenly there was darkness as the darkness of night, when all became fire, and terrible and wonderful things happened, of which there can be no words. As in all things that the native can not understand, there was a distinct aversion to talking about it. All my questions met with a similar response, and they rapidly changed the subject. The other main stream which flowed down the northwest slope was of enormous extent, but as I merely crossed it I had no opportunity of accurately estimating the area covered. Besides a small branch about 400 yards wide, the width at my crossing was about 2 miles, and this was well on the slope of the hill; farther down, where it met the eastern main stream, the width of the two combined can not have been less than 15 miles. In the plain to the north of Kivu, in the pass between the two blocks of volcanoes, and on the slopes to the north, owing to the porous nature of the ground, there is no water; yet, in spite of this, there is an enormous population, the necessary water being obtained by tapping the stems of the banana palms. The moisture is retained by the ground, and consequently the forests that clothe the slopes of the volcanoes are wildly luxuriant and impenetrable to everything but the elephant. When hunting and following close on the tracks of an elephant we had to cut our way with a native ax, without which no one moves a yard. For hundreds of yards at a time one never touched the ground, but was climbing along the prostrate tree trunks and dense growth, which, of course, the elephant would take in its stride. More desperate work or more dangerous hunting it would be impossible to conceive.

Although the forests were full of elephants, it was only after a week's terrible work that I found one; and then I had to fire at him at 2 yards, as, if I stepped back, I could no longer see him. It was impossible to creep to either side of him, so impenetrable was the undergrowth, and I had perforce to take the shot as it was or lose the chance. The effect on the sportsman of firing a double four bore at such close quarters can be better imagined than described. As for the elephant, I believe he is still running. The next day I followed up another, and, after knocking him down three times, was furiously charged and either kicked or carried by the rush on to some thorn tree 10 feet above the ground, my gun being picked up 10 yards away in the opposite direction, full of blood. I could not see him till his head was right above me, when I pulled off both barrels of the 0.500 magnum that I was carrying. This evidently turned him. I was pulled down from my spiky perch by my niggers, who, seeing me drenched with blood, thought I must be dead, till an examination proved that it was the elephant's blood. On resuming the chase he got my wind again, but fearing the charge, merely let off some superfluous steam in throwing trees about—a performance that so impressed me that I have never tackled an elephant with any degree of comfort since. After ten minutes of this exhausting display he fell down, but pulled himself together again and went straight away, and though I followed him till it was too dark to see, I never found him. We had had neither food nor water all day, and it rained all night, necessitating a hungry and chilly vigil, during which I had ample time for calm reflection—reflection which ended in the conclusion that elephant hunting in the scale of sports might be placed between croquet and marbles. Sharp, after losing 2 stone in herculean efforts, never even saw one, and gave it up in disgust.

Of the four main peaks of the eastern mass of volcanoes, all of which are extinct, the highest I have described as Mount Eyres, after Mrs. Eyres, of Dumbleton Hall, Evesham, Sharp's sister, without whose help and encouragement we should have failed to bring our trip to a satisfactory conclusion. The other high peak I have described as Mount Kandt, after the distinguished German scientist, who is making a most elaborate study of the whole region. Nearly every morning there was snow on these two peaks, and the height of Mount Eyres must be nearly 13,000 feet (?), as during my elephant hunting, when I explored all the northwest face, my aneroid registered on one occasion more than 11,000 feet. Leaving the elephant, I made a rapid tour to establish the identity of Mfumbiro, which is conspicuously marked on most maps, with the height added, and I ascertained for certain what I had been led by the Germans to suspect, namely, that Mfumbiro has never existed outside the imagination of the British statesman. Mfumbiro, it will be remembered, was accepted by us from the Germans as a counterpoise to Kilimanjaro, which we gave to them in our usual open-handed manner in the boundary agreement between British East Africa and German East Africa. The forests of these volcanoes are a branch of the great Aruwimi forest, and the home of numbers of pygmies, who hunt the elephant and search for bees, trading the meat and honey with the Waruanda for grain, spear and arrowheads, and knives; while the Waruanda buy their bows and arrows complete, the dwarfs' work being much superior to their own.

When making the circuit of the two active volcanoes, I had an unpleasant experience with a tribe of cannibals called the Baleka, who made what had lately been a delightful and thriving district most undesirably warm. Their superfluous attentions and the absence of food prevented me from exploring two small lakes that I saw to the west, and from determining whether the large stream, which I could see issuing from the southern lake, flowed into Kivu or down the other side of the watershed direct into one of the tributaries of the Kongo. Four days' continual marching, during which I and my ten boys suffered much from hunger, took us out of the country in time to warn Sharp, who was coming round the south of Mount Götzen to meet me with the rest of the caravan. Joining forces again, we returned through the pass once more, and started down the Ruchuru, or, as it is here called, the Kako Valley. The Kako rises on the north slopes of the volcanoes, and, becoming farther north the Ruchuru, flows into the Albert Edward Lake; hence its headwaters are the true source of the Albert Nile. Curiously enough, the source of the Victoria Nile is only 40 miles south of this, the headwaters of the Nyavalongo, which is the main tributary of the Kagera, the main feeder of the Victoria Lake, rising a few miles from Kivu. Thus within six days we passed the two actual sources of the Nile, which, rising close together, but flowing in different directions, inclose such a vast tract of country before they finally merge at the north end of the Albert Lake preparatory to the long voyage via Khartoum to the Mediterranean. The height of the crest of the pass is 7,000 feet, and the ground quickly falls away to the north till one drops to the dead level of the vast Albert Edward plains.

When exploring with a small number of followers, I observed some ape-like creatures leering at me from behind banana palms, and with considerable difficulty my Ruanda guide induced one of them to come and be inspected; he was a tall man, with the long arms, pendant paunch, and short legs of the ape, pronouncedly microcephalous and prognathous. At first he was terribly alarmed, but soon gained confidence, and when I asked him about elephant and other game, he gave me most realistic representations of them and of how they should be attacked. I failed to exactly define their social status, but from the contempt in which they were held by the Waruanda their local caste must be very low. The stamp of the brute was so strong on them that I should place them lower in the human scale than any other natives I have seen in Africa. Their type is totally distinct from the other peoples, and, judging from the twenty to thirty specimens I saw, very consistent. Their face, body, and limbs are covered with wiry hair, and the hang of the long powerful arms, the slight stoop of the trunk, and the hunted, vacant expression of the face made up a tout ensemble that was a terrible pictorial proof of Darwinism. The pygmies are of similar build, but have the appearance of full-grown, exceedingly powerful men compressed, and with much more intelligent faces. The pygmies are to these ape-like beings as the dog-faced baboons are to the gorillas. Probably they are, like the pygmies, survivals of former inhabitants of the country, the difference in their type depending on the surroundings in which they have had to struggle for existence. The true type of pygmy is a magnificent example of nature's adaptability, being a combination of immense strength, necessary for the precarious hunting life they lead, and compactness indispensable to rapid movement in dense forest where the pig runs are the only means of passage. While I was with the main caravan I never saw either a pygmy or one of these creatures, and to study them it is necessary to go almost unattended; this obviously entails great risk, and it is consequently very difficult to find out much about them. They both have the furtive way of looking at you characteristic of the wild animal, and though I had one of these curious men with me for a week when I made the circuit of the volcanoes, he would always start if I looked at him, and he followed my every move with his eyes as would a nervous dog; he refused an offer of cloth for his services, and suddenly vanished into the forest without a word, though several times afterwards I found him watching me even when I had returned to my camp on the base of Mount Eyres.

On the last spur of the volcanoes there is a chief called Kahanga, of some little importance, who has, to a great extent, emancipated himself from the yoke of the Watusi; and farther down the Ruchuru Valley the people are still more independent, till one comes to a thickly-populated area two days from the Albert Edward, where the chiefs deny that they owe any allegiance whatever to the Kigeri. The west side of the valley is covered with heavy forest, while the east side is undulating grass land, till 15 miles from the lake, when the country settles down into one vast plain. The Ruchuru here has become almost too salt to drink, and the vegetation changes abruptly in character, the luxuriant forest growth giving way to thorn scrub and candelabra euphorbia, the beginning of the blighted desolation characteristic of the Albert Nile Valley—scrub, mimosa trees, fan palm, and euphorbia alternating till the region of the borassus, which begins at the upper junction of the Bahr-el-Giraffe.

Where the Ruchuru flows into the Albert Edward there is a large extent of reedy marsh, peopled by a race of fishermen who appear to be identical with the curious Wanyabuga who inhabit the similar country at the entrance of the Semliki into the Albert Lake. They are both quite distinct from their neighbors, and are now isolated. I am inclined to think that they, too, are survivors of past races, who are making a last stand for existence in these impenetrable wastes, where, leading an amphibious life that does not bring them into contact with the more sturdy races who have supplanted them, they may yet give an important clue to the ethnological problem of Africa. Unfortunately, the difficulty of approaching these timid and retiring peoples, and the thoroughness with which contiguous peoples assimilate the prevailing tongue, the study is one of great difficulty. The lake itself is rapidly diminishing in extent, and it will be seen that our map of the east coast has materially modified the supposed form. Two very recent levels are clearly defined, from which it would appear that the upheaval has taken place in fits and starts. The most recent level would give the lake an additional 120 square miles. The insignificant size of the euphorbia on this level compared with that on the next terrace argues that the last movement has taken place very recently, historically speaking. The vegetation appeared to me to correspond in age to that which I have mentioned as having grown on the great lava beds poured out by the eruption previous to that of three years ago.

Two streams, the Sasa and the Ntungwe, flow to the Albert Edward east of the Ruchuru, but lose themselves in an extensive marsh. The old lake bed is rendered impassable by pits of fire, and huge jets of smoke, shooting up from all directions, bear witness to the extent of the volcanic activity. Even to unscientific observers like ourselves, it was evident that the country between Kivu and the Albert Edward is the key to the whole modern geographical and geological problem of Africa, as probably Ruwenzori is the key to the problem of the past. To summarize: The Rusisi Valley for 60 miles is obviously the old lake bed of Tanganyika. Lake Kivu has been lifted up with the gradual rise centering round and radiating north and south from the volcanoes. The surrounding hills still inclose papyrus swamps at the lake level, and some of these, having been pushed up by local movement, have become dry lawns.

I can only describe the Kivu region as having the appearance of having bubbled. The north shore of Kivu is flat and slopes gradually up to the volcanoes, sloping down gradually again on the north side, till the dead level of the lower Ruchuru Valley is reached—another obvious lake bed, part of which was drained dry but yesterday. A few small lakelets even are held still on this northern slope, and there are many marshes and lagoons on the dead level. North of Lake Albert Edward we find the old disturbing influence, Ruwenzori. But Lake Ruisamba and its surrounding swamps to the east and the Semliki Valley to the west carry on the idea. The northern half of the Semliki Valley is a dead level with many swamps, and then comes the Albert lake.

The lakelike reach of the Nile, narrowing at the Dufile Rapids (another center of disturbance in remote ages), and again widening till the swamps of the Rohl Bahr-el-Ghazal, Bahr-el-Jebel, and Bahr-el-Zaraf, which can only be adequately described as a reed-grown sea, is a further indication of the probability of an existence of a vast inland sea, or arm of the sea, of which the great African lakes of to-day are but a fragmentary survival.

The east coast of the Albert Edward lake is practically uninhabited; a very few miserable natives live in the dense thickets of thorn bush, and their huts are most carefully concealed. Their staple crop is the sweet potato, and they spear fish and kill an occasional hippopotamus in traps. They complained of having been raided by the people of Ankoli. On arrival at the north end, Kaihura ferried us and all our belongings across the narrow neck of Lake Ruisamba. Their canoes are similar in make to the Waganda, but not of such elaborate design, being made of ax-hewn boards, sewn together with banana-fiber cord; they are very capacious, and are so well fitted that they leak much less than would be expected from their construction. The Sudanese officer at Katwe entertained us for two days, when, having recovered sufficiently from the severe fever from which I had been suffering, we started for Toro, and six days later arrived at Fort Gerry, the headquarters of the district. There are immense numbers of elephants in Toro, and we went up to the Msisi River, which flows into the southeast corner of Lake Albert, for a fortnight's shooting. Being white men, we had the privilege of paying a £25 license, which enabled us to shoot two elephants; but our sport was spoilt by bands of Waganda, who had crossed the frontier and were shooting indiscriminately anything with a trunk, regardles of sex or age. Needless to say they paid nothing. Nothing could be more acceptable than game laws and game preserves intended to restrict the indiscriminate shooting of big game; but before the Government is capable of enforcing them or even of knowing when they are ignored, I think they are premature. Here, to my great regret, Sharp was forced to return home, and I had to continue my journey alone. Thirty of our Manyema volunteered to go on with me as far as Wadelai, and with this reduced caravan I marched by the little volcanic lakes Vijongo and around the northern spur of Ruwenzori to the Semliki Valley, which I crossed, climbing up again on to the Kongo plateau. Here, on the west side of Mboga, I stayed for three weeks hunting elephant, my best tusks being 98 pounds and 86 pounds; these, curiously enough, were obtained the same day from two single-tusked elephants, one being a right tusk and the other a left, and each measured 7 feet 10 inches.

In this country the prevailing type of elephant differed considerably from the Toro and Nile type. Full-grown bulls carrying 70, 80, and 90 pounds tusks stood no higher than 9 feet at the shoulder; whereas two of the other type I measured were a full 11 feet 6 inches, and several over 11 feet. The ivory was also quite different—the Mboga tusks being long, thin, and almost straight, very white, and free from cracks; as opposed to the curly, dull white tusks, covered with small cracks, of the heavier beast. The tusks of the Mboga elephant are set in the skull at a different angle and hang straight down, giving the beast the appearance of having three trunks; while the tusks of the more general type curl out in front almost at right angles.

The Balegga who inhabit the hills of the north, and who were suffering terribly from the effects of the long drought, looked upon me as a great institution, and swarmed down in hundreds for the meat. A weird sight it was. Stark naked savages, with long, greased plaits of hair hanging down to their shoulders, were perched on every available inch of the carcass, hacking away with knives and spears, yelling, whooping, wrestling, cursing, and munching, covered with blood and entrails; the newcomers tearing off lumps of meat and swallowing them raw, the earlier arrivals defending great lumps of offal and other delicacies, while others were crawling in and out of the intestines like so many prairie marmots. Old men, young men, prehistoric hags, babies, one and all gorging or gorged, smearing themselves with blood, laughing, and fighting. Pools of blood, strips of hide, vast bones, blocks of meat, individuals who had not dined wisely but too well, lay around in bewildering confusion, and in two short hours all was finished. Nothing remained but the great gaunt ribs like the skeleton of a shipwreck, and a few disconsolate-looking vultures perched thereon.

Returning to the Semliki, I followed the valley down to the Albert Lake, and eventually arrived at the scene of the relief of Emin. Here it was impossible to obtain food; the natives had been raided and shot down by the Kongo State soldiers, and had fled to the marshes and reed-beds of the Semliki mouth. After some difficulty I persuaded them that I was of the same tribe as Colonel Lugard, and being satisfied by a production of his photo, their confidence in me was complete. As this territory is British, the charge against the Belgians is a serious one, and I am perfectly convinced that the gist of their accusations is correct; minute inquiries and cross-questioning failed to detect a flaw, and the tale, which was repeated to me in districts as far distant from one another as Mboga and Kavalli's, tallied in all respects, even in the numbers of women and cattle driven off and men killed. At five distinct villages, three of which were Wanyabuga villages and two Wakoba villages, I was assured that the old women were treated with the greatest cruelty. Three distinct tribes, the Balegga, Wanyabuga, and Wakoba, told the same story. This I considered sufficiently conclusive, as there is very little intertribal communication, and it could not have been a "put-up job," as my Balegga informants were 60 miles away from the others.

The journey up the west coast presented considerable difficulties, as after Kahoma the hills descend abruptly into the water, rocky headlands alternating with semicircular beaches (the deposits of the numerous streams which flow down into the lake). In parts the lake is exceedingly shallow, reeds growing at a distance of 2 miles from the shore; and the deposit brought down by these numerous mountain torrents must be enormous. This coast is of value for the magnificent timber that grows in all the gorges. Transporting the loads round the headlands in two tiny dugout canoes holding one load at a time was tedious work, and I was exceedingly glad to arrive at Mahagi, where the hills recede once more. From Wadelai, the British post on the Nile, I went to Afuddu (opposite Dufile) in a dugout canoe, and thence overland to Fort Berkeley (the old Bedden), our advance post. Inspector Chaltin, the able administrator of the Welle district of the Kongo and the gallant conqueror of the Dervishes at Rejaf, kindly took me down to Kero, their advance post on parallel five and one-half, in one of their numerous steel whaleboats. Thence I traveled to Bohr with the Commandant Renier, who was sent to find news of the steamer with Captain Gage, Dr. Milne, and Commandant Henri, which had been away three months on a reconnoissance toward Khartoum.

Bohr had been recently evacuated by the dervishes, and the strong fort was still in good preservation. Throwing away everything but absolute necessaries, I started with thirteen men on my 400 miles tramp through unknown swamp with many misgivings. The first two days the Dinkas were quite amenable to treatment, having been in contact with white men before. But afterwards I had a very anxious time with the natives, as in places they were in enormous numbers, and, having never seen a white man, were quite ignorant of his ways, and even of the use of a gun. For some distance on the edge of the marsh there is a clearly defined stream, which loses itself in the vast lagoons that form near the upper junction of the Bahr-el-Zaraf. Many winding lagoons run for miles inland. When I passed they were stagnant, but I am inclined to think that they are really the outlets of tributary streams. The number of elephant on the edge of the swamp was prodigious, and they formed a serious impediment to our march, as they refused to move out of the way. Nearly every morning we wasted an hour or two shouting and throwing stones at solitary old tuskers and herds of younger elephant. One old fellow resented our terms of opprobrium and charged the caravan, but was turned with a shot from my double .303. Banks and banks of hippopotami lay in every direction, but other game was scarce. The mosquitoes were appalling, and rapidly killed off two of my boys who had been sick; and the flies by day were even worse.

The Dinkas have enormous droves of cattle, which they value very highly; they never kill them for food, but from time to time tap the blood, which they drink greedily. They are of colossal stature; some of the herdmen I saw must have been very nearly 7 feet, and in every settlement the majority of the men towered above me, while my boys seemed the merest pygmies by their side. They smear themselves with a paste made of wood ash to protect themselves from the bites of the mosquitoes, and the long lines of warriors threading their way in single file through the marsh appear like so many gray spectres. They are absolutely nude, considering any sort of covering as effeminate. Their invariable weapons are a long club made of bastard ebony, a fish lance, and a broad-bladed spear, and the chiefs wear enormous ivory bracelets. The southern Dinkas cut their hair like a cock's comb, and the northern Dinkas train their hair like a mop. Both bleach it with manure.

Six days from Bohr the bush recedes 40 miles from the main channel of the Nile, and the swamp appears limitless; even from an anthill 30 feet high I could see nothing but a vast sea of reeds north, west, and south—not even the remotest suggestion of the far bank. At the curve of the swamp, before the dry ground again turns west toward the junction of the Bahr-el-Zaraf, there is a tribe quite distinct from the Dinkas, presumably the Woatcsh, of whom Sir Samuel Baker heard rumors. They are much smaller, and are ichthyophagic, possessing no cattle. The whole population of each village turned out in force and accompanied me to the next village, singing a wild ear-piercing chant, and continuously pointing to the sun. I suppose they imagined I had just left there. Some of the villages are far inland, and the women come long distances for water. I met many groups of them filling their pitchers, and they invariably treated me to a somewhat embarrassing dance; it was characterized by the wildest abandon, and terminated in every one hurling themselves in a mass on the ground and then dashing off in all directions into the bush, uttering shrieks impossible to describe. When I showed them beads or cloth and attempted to purchase food, they ran away, hiding their faces, and refused to look at them, thinking they were fetich. Even at night bands of natives would approach and chant to me, so that I was greatly relieved to once more enter the land of the Dinkas, who, even though rather obstreperous, at least refrained from singing. A remarkable thing was the extraordinary manner in which the Dinkas contrived to conceal their enormous herds of cattle until they were quite sure of my intentions; they kept them quiet by lighting small smoke fires under their nostrils, and we often walked right into the middle of a cattle village before we were aware of their proximity. A few miles north of the upper junction of the Bahr-el-Zaraf, a considerable stream flows from the east, which I am inclined to think flows from the marshes in which the Pibro, the large affluent of the Sobat, rises. For 30 miles at least it flows due east to west, and I am sure that it can not rise in the Gondokoro hills, as suggested by Justus Perthes's map. Any drainage that comes from these hills must, from the contour of the country, flow into the Nile or into the marsh by the long lagoons that I have already mentioned, or down the other side of the watershed into the Sobat. Should my surmise as to the source of this affluent prove correct, the country between the Zaraf and Sobat is an island. The natives at Bohr assured me that there was no water for many days east, and there was a considerable amount of water coming down the affluent in question. This would suggest that the streams passed by Lupton Bey in his journey east of Lado either drain into the Nile south of Bohr, or, what is more probable, into the marshes of the Pibro.

This Kohr is the northern boundary of the Dinkas. Shortly before reaching it I was treacherously attacked by the inhabitants of the village near which I had camped. They gave some trouble in camp during the evening, but appeared quite friendly in the morning, and turned out to the number of about 100 to accompany me on the march, as had often happened to me before. Sometimes there were fully 1,000 natives with me; they took me as a huge jest, and wanted to see as much of it as possible. I had noticed that they were crowding round me, when suddenly they started, killed my best man with a spear wound through the heart, and broke the skulls of two more; the rest threw down their loads and bolted, my small boy with my revolver among the rest. A quick right and left laid out the chief and his prime minister, and I swung round just in time to dodge a spear and to ward a blow at my head from a club, which felled me to my knees. I responded by poking my empty rifle in the pit of his stomach, and the ensuing pause gave me time to slip in a cartridge and finish him. The rest then drew off to about 300 yards, which they evidently considered a safe distance. An enormous man, of about 6 feet 6 inches, who had caused most of the trouble in camp, tried to lead them on again, and if he is still alive he knows more about the effects of a dumdum bullet than most men. I should much like to have given them a severe lesson, but, as I had very few cartridges, I knocked another gentleman off an ant-hill at long range, and, having thus given them an idea of the uses of a gun, made forced marches out of the country, fearing that they might return in overwhelming numbers. One of my boys, who lagged behind for a few moments despite my repeated warnings, vanished completely.

The Nuers are similar in appearance to the Dinkas, but rather smaller; they wear iron earrings, some of which were a foot in diameter, and cultivate their hair with the greatest care, binding it up with rings of cowries. Their method of showing respect, as with the Dinkas, is spitting on the object of their attentions. The last ten days of the march were terrible. Far as the eye could reach, one vast shimmering waste of burnt reed, sun-baked mud, and marabout storks; the Zaraf flowing between parallel mud banks, lined with crocodiles; never a native, never a living beast, with the exception of the dismal hoppos, solemn marabouts, and screaming kites; no trees, no bushes, no grass; nothing even to boil a cup of tea, and our diet of hippo meat or pelican steak, with no bread or even grain, was rapidly telling on our health; so that it was a moment of intense joy when I unexpectedly met Major Dunn, of Major Peake's sudd-cutting expedition, who was up the Zaraf shooting.

It was difficult to realize that it was at last over. From Sobat to Cairo was covered in a fortnight of wild hospitality, a distance equal to that which had necessitated eighteen months of weary toil. The maps were worked out with a watch and prismatic compass and aneroid; to regulate my errors, I took Usambara, Vichumbi, and Katwe as fixed points. We were unfortunate in having to leave our theodolite behind for lack of transport, and in losing our sextant and boiling-point thermometer in a raid that the Waruanda made on us one night at the beginning of our trip. The exceedingly hilly nature of part of the country traversed added to the difficulty of judging distance covered. However, I trust that the maps will more or less serve the purpose for which I intended them—that of clearly showing what difficulties the railway and telegraph will have to contend with—such as physical features, labor, and supplies. The immense difficulties of transport and the work entailed in keeping a caravan thoroughly in hand, which is so essential when traveling without an armed force, precluded all possibility of making collections; and our photographic apparatus was spoilt by the negligence of the transport company that undertook its delivery. We are proud to be able to say that on one single occasion only we found it necessary to take food from the natives; they had all fled, and I took out ten men and cut about thirty bunches of bananas. I have always believed that more can be done with natives by tact and firmness than by a display of force, which makes them believe that their country is threatened; and certainly they nowhere imagined that we, with our ten rifles, had any warlike intentions. On only two occasions was I compelled to take life, and that in self-defense when actually attacked. Attacking people in case they may attack you, I have seen recommended, but I think it a superfluous and questionable precaution. Even the people of whom Sir Henry Stanley writes, "Marching to Wadelai would only be a useless waste of ammunition," I found perfectly tractable, and that although they have since his visit been subjected to the disturbing influence of the Belgian raid on Kavalli, and of the twenty rounds that I took with me I found it unnecessary to use one.

Before the reading of the paper, the president said: "This evening we have the pleasure of welcoming our young friend Mr. Grogan, who has succeeded in making a most important and interesting journey from the Cape to the Mediterranean. That has been done by him for the first time, and so far as geographical work is concerned, he has much here to tell us, especially in the region north of Lake Tanganyika."

After the reading of the paper, the following discussion took place:

The **President**. Mr. Grogan has mentioned to me the immense importance it was to him to have had such a traveling companion as Mr. Sharp, and he felt it as a great loss when Mr. Sharp had to leave him to return by way of Uganda. We can imagine how important it must have been on such an expedition to have a good, well-tried companion. Mr. Sharp is here this evening, and perhaps he will address the meeting.

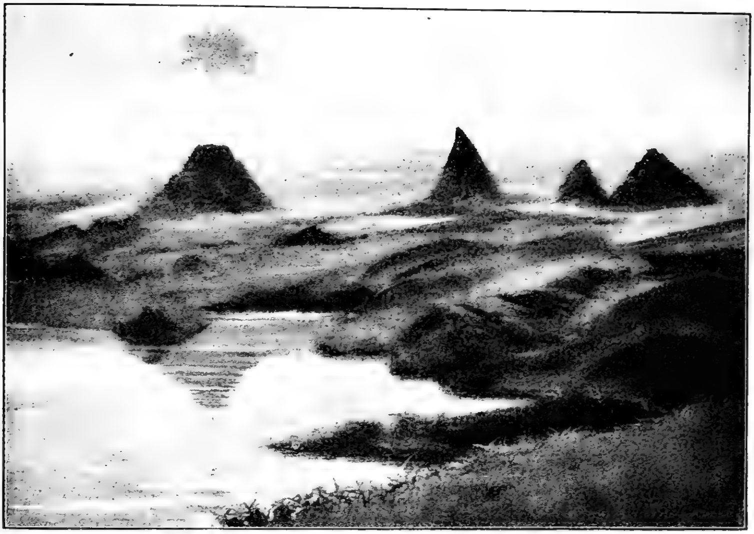
Very often great travelers are too modest to address meetings of this kind, but we have present this evening the members of an international convention which, I believe, is assembled in London at present in order to take some international measures to prevent the total extirpation of wild animals in Africa; already three, besides the quagga, are extinct. Among other delegates we have one of the greatest of African travelers, Major Wissmann, and I trust that he, taking so deep an interest in Mr. Grogan's journey, will address a few words to us.

Major **Wissmann**. The only fault I can find with the lecture we have just heard is that it was too short. We should all have liked to have heard more details about these interesting travels and observations. You can imagine how eagerly I look forward to some detailed description, because Mr. Grogan touched, going from the Zambezi to the north of Tanganyika, my tracks of 1881, 1887, and 1892. We may all, I think, congratulate Mr. Grogan on his great ability in dealing with the natives. The idea that first journeys are always the most dangerous, is wrong; at least, I have always traveled more safely where no other European or Arab has been before me. The first contact with the new civilization is not always the test for the savages. The way in which Mr. Grogan has traveled through the countries of tribes bearing a very bad reputation is surprising. The famous Mfumbiro, which Mr. Grogan maintains exists only in the imagination of British statesmen, has been found by a German traveler, or rather its name was recognized, because I think Mr. Grogan saw the mountain under another name.

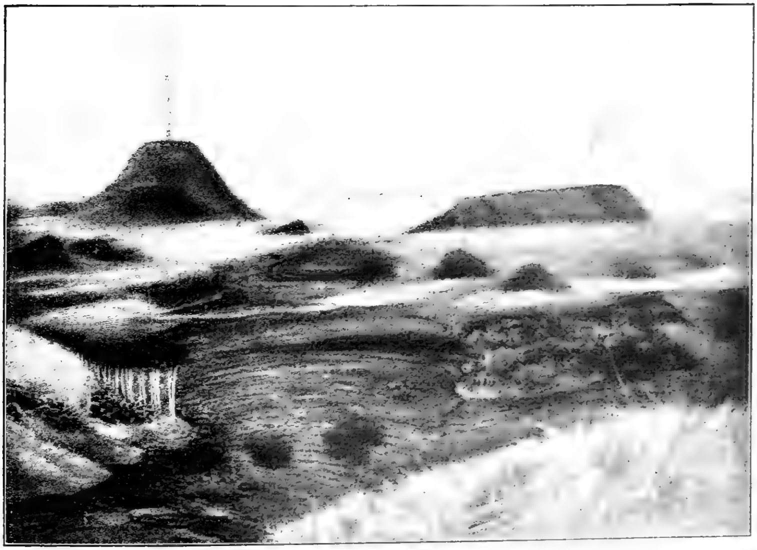
The PRESIDENT. We have also a very illustrious French traveler present. I am afraid he is not very conversant with our language, but if Captain Binger, who has done so much important work on the Niger, cares to address us in French, we shall be glad to welcome him here this evening.

We must all have listened to Mr. Grogan's paper with great interest. He has made a most remarkable journey. He is the first to go over that enormously long line of country, which is eventually to carry a railroad, but I am afraid, from the difficulties he has described, that it will be a long time hence. In the meanwhile Mr. Grogan has made a most remarkable journey. Much of his work is of great interest and new to us, including that swamp he visited on the Chambezi, and the extremely interesting description he has given us of that previously unknown, or almost unknown, volcanic region to the south of the Albert Edward Lake. He deserves the greatest credit for the observations he has made and the care he has taken in making notes of all he has seen of interest to geographers. So young a man—for he is only 25 years of age—may look forward to a long career as a geographical explorer. I am sure you will wish me to express to him your thanks for his paper and the interesting photographs; also, to express a hope that it will not be a very long time hence before he comes to us with another paper, if possible of still greater interest and importance. It will be a very great mistake indeed for us to suppose that there is nothing left to discover. There are vast regions in all quarters of the globe, besides the arctic and antarctic regions, which are entirely unknown, and I look forward to such young men as Mr. Grogan to vie with the geographers of other countries in exploring unknown regions.

I have great pleasure in conveying to Mr. Grogan the thanks of the meeting for his most interesting paper.

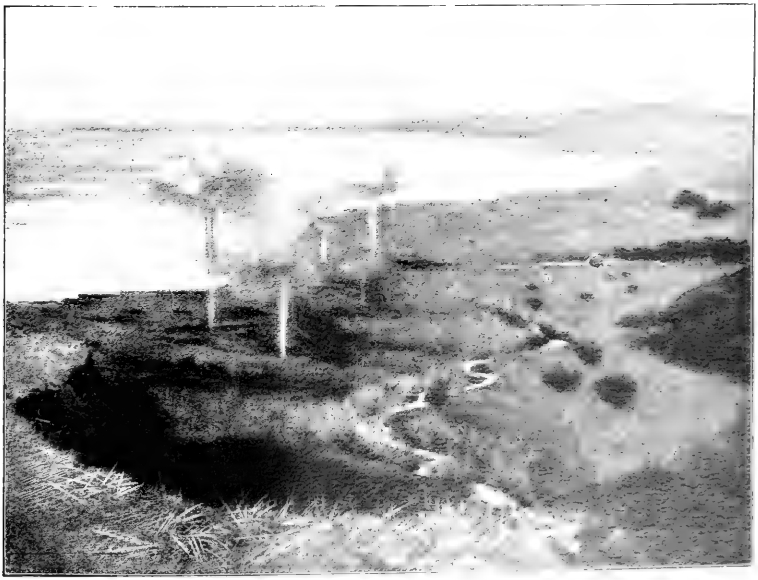


THE VOLCANOES FROM LAKE KIVU. VIEW FROM SOUTHEAST.

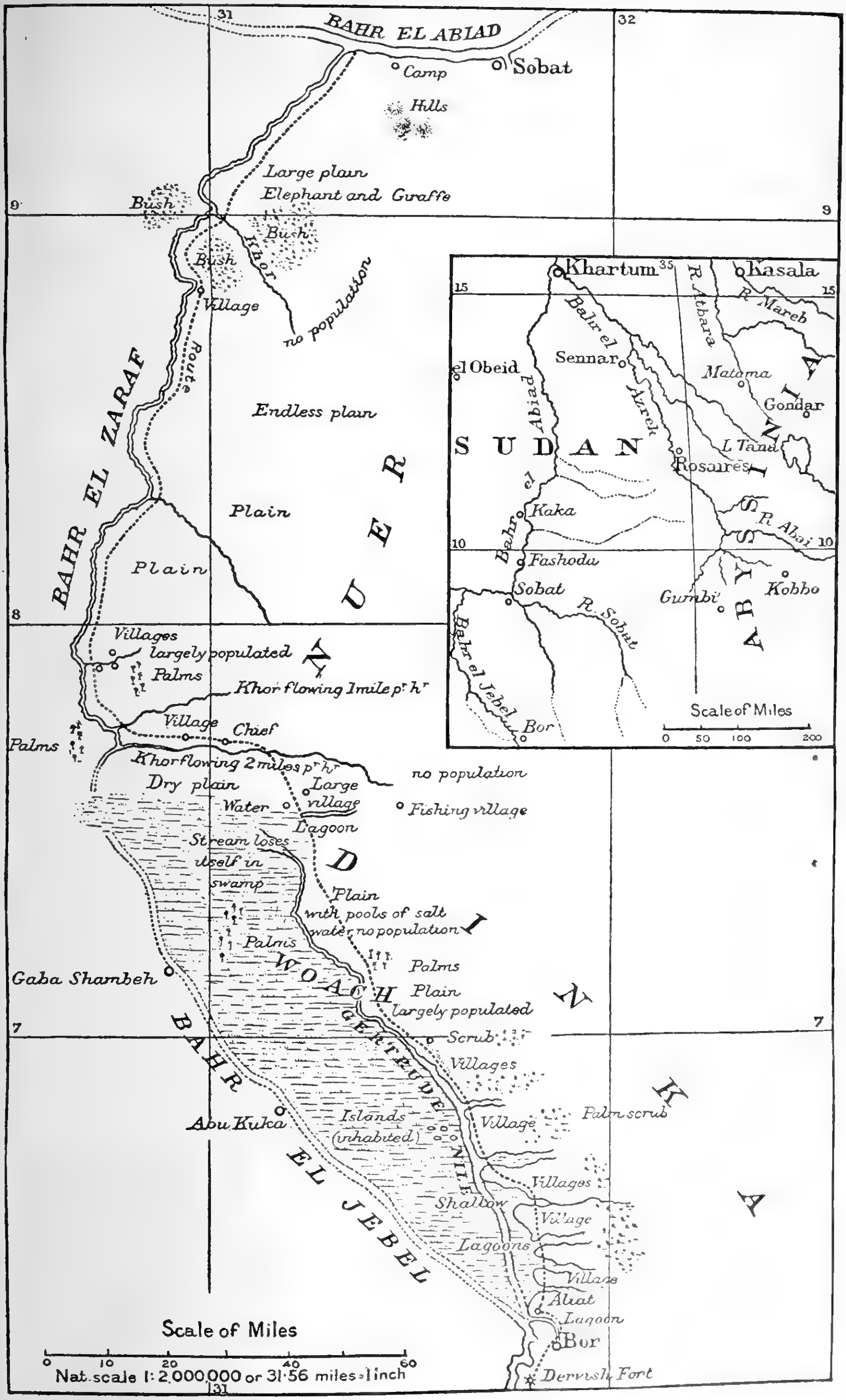


THE VOLCANOES MOUNT GÖTZEN AND MOUNT SHARP, FROM THE NORTHEAST.

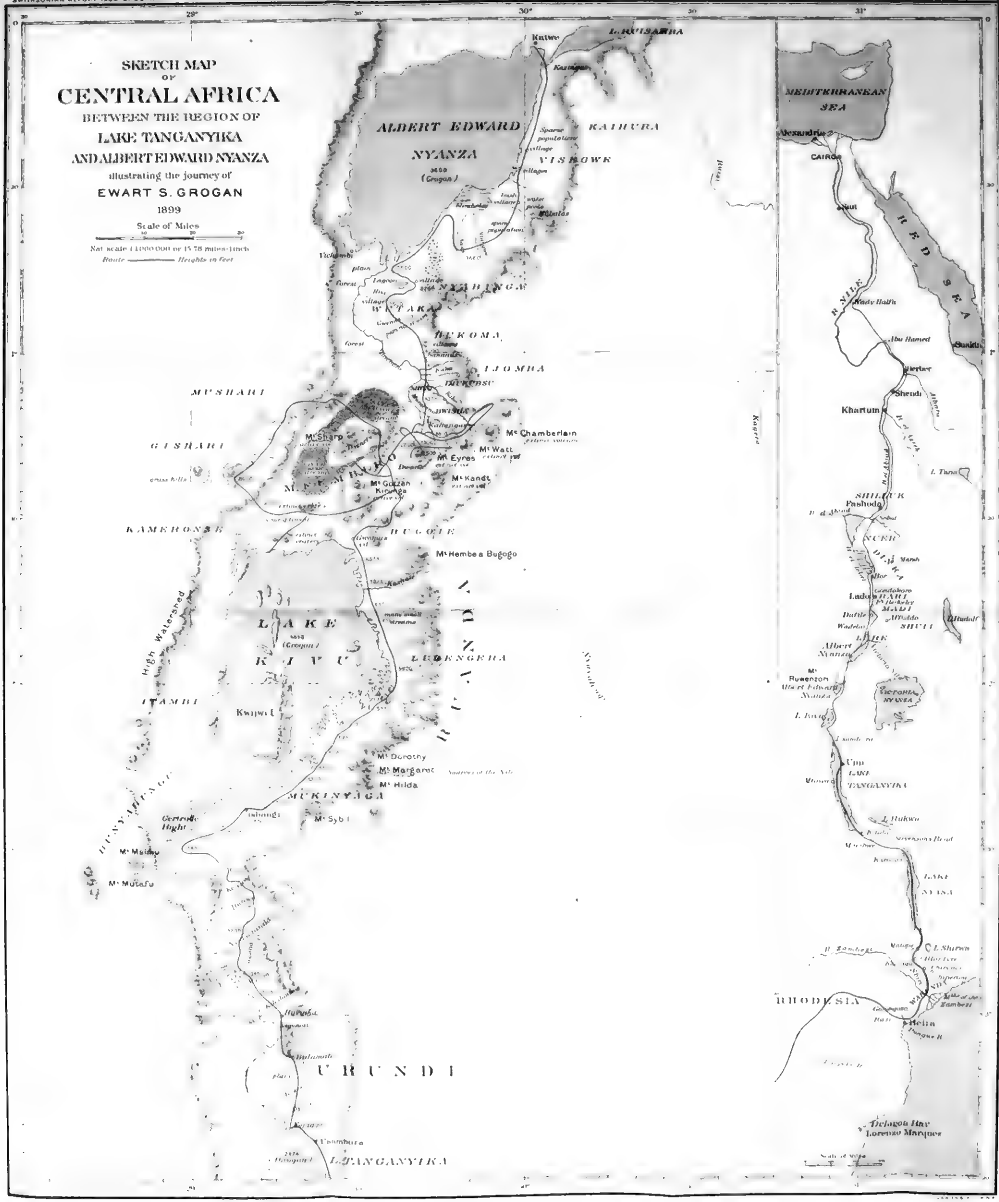
RUWENZORI, FROM THE WEST.



THE GEYSERS, ALBERT EDWARD NYANZA.



THE SWAMPS OF THE DINKA COUNTRY.



SKETCH MAP
OF
CENTRAL AFRICA
BETWEEN THE REGION OF
LAKE TANGANYIKA
AND ALBERT EDWARD NYANZA
illustrating the journey of
EWART S. GROGAN
1899

Scale of Miles

Nat. scale 1:1 000 000 or 15·78 miles=1 inch

Route ——— Heights in feet

THE "YERMAK" ICE BREAKER.[1]

By Vice-Admiral Makaroff, of the Russian Imperial Navy.

The old way of traveling in the polar regions was by means of dogs and sledges. Dr. Nansen proposed to travel with the ship, making her so strong as to resist the pressure of the polar ice. He succeeded in this perfectly well; his ship could stand the attacks of the polar ice, and his defensive tactics proved to be very efficient. Just at the time when Dr. Nansen proposed to build his *Fram*, I had the idea of adopting offensive tactics against the polar ice. I was engaged at that time with my service, and did not then see my way to disclose my ideas, but I made some preliminary preparations. I wrote to Dr. Nansen a letter, in which I stated that I was entirely of his opinion, that he would be carried by the currents somewhere in the direction he imagined, and advised him that help should be sent for him to Franz Josef Land. My letter to him and his answer were duly published in the Russian newspapers and in geographical publications. I thought it quite possible that he would not complete his voyage in three years; I also thought that, if in four years nothing was heard of him, people would be anxious to send help, and that would be a good pretext for collecting money.

In my opinion the best way to penetrate into the Arctic regions is by means of a powerful ice breaker. Certainly I did not wish to mention in my letter to Dr. Nansen that I would go and help him, because being on Government service, I could not dispose of myself. But I asked him in my letter if he had any intention of leaving any trace of his voyage. He replied that he intended to put on every island that he might discover a pole with a small Norwegian flag on it, and under that pole a letter with information about the voyage of his ship. Fortunately for Dr. Nansen, the current carried him on very well, and on my return from the Pacific station I was happy to learn that he and his *Fram* had safely returned home. Of course that deprived me of my excuse for collecting the necessary money for building a large ice breaker, but I found another motive, this time purely commercial.

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[1] From The Geographical Journal, London, Vol. XV, No. 1, January, 1900.

I proposed to build an ice breaker, which in winter time might clear the way through the ice to the port of St. Petersburg and in summer time help the navigation to the Siberian rivers flowing into the Kara Sea, barricaded by ice almost during the whole summer.

The ice breaker was built here in England by Sir W. G. Armstrong, Whitworth & Co., Limited, and the name of the conqueror of Siberia, *Yermak*, was given to her. Her length is 305 feet; breadth, 71 feet; displacement, with 3,000 tons of coal, 8,000 tons; and in this condition she draws 25 feet. Her bow is inclined 70° from the vertical, her stern is 65°, and her sides are 20° from the vertical. In whichever direction she moves in the ice she is bound to rise on it and break it with her weight. She has four engines, working four independent propellers—one in front and three at the stern. Each engine develops 2,500 horsepower, so that the total force of the ship is 10,000 horsepower. The ship has a double bottom and double sides. She is divided into forty-eight compartments, every one of which was tried by filling with water as high as the upper deck. One compartment in the fore part of the ship, one at the stern, and two at both sides are specially designed for changing the trim and heel of the ship. In the center of the *Yermak* is situated a powerful pump, which can take water from any of these compartments and pump into the other. Each propeller is supplied with extra auxiliary engine, so that the main engine can be disconnected if necessary and the propeller worked from the auxiliary engine. This was meant to give economy of fuel when the ship has to go under ordinary conditions and reduces the number of mechanical staff. The ship has a rolling chamber to keep her steady, and a lifting crow's-nest, which affords facilities for directing her through the ice.

I selected a very distinguished officer, Captain Wasilieff, to command the *Yermak* during the experiments, but I was on board myself on every important occasion.

Her maiden voyage was from Newcastle to St. Petersburg. We entered the ice at the meridian of Revel, and had to force our way through 160 miles of ice. It never occurred to any one that the ship would go to Cronstadt in winter time, and our entering Cronstadt harbor caused quite a sensation.

The limits of this paper does not allow me to give details of our performance in the Baltic. Soon after our arrival in Cronstadt a telegram was received that thirteen steamers were caught in the ice near Revel, and some of them were in danger. The *Yermak* went at once to Revel and opened the way for these and other steamers, the total being forty-one, partly blocked in the ice and partly waiting in Revel Harbor and other ports for several weeks. This work done, the *Yermak* proceeded again to Cronstadt, and helped forty steamers going to St. Petersburg. After this was done the ship proceeded to Newcastle to take in a supply of coal.

The ship was built for the Kara Sea, where is one year's ice, but it was resolved to try the ship in heavy polar ice. In the month of June we made our first trial in the polar ice, and found that the ship had to be strengthened and the forward propeller taken out. Then we returned to Newcastle, and on August 6 we entered again the polar ice. This time we were in the ice two weeks, covering during that period 230 miles in 87 hours.

We entered the ice to the northwest of Spitsbergen on August 6 at noon, and in eight hours made, in the ice, about 30 miles to the north, going always in a zigzag route. Then we stopped almost for three days, examining the ice and the ship itself. During that period we were drifted west-southwest at the rate of 10 miles a day, the wind being north. Then we made again 10 miles to the north, and stopped for a day, and in eleven hours made 30 miles to the north again, the wind always blowing from a northerly direction. At this last place we met an ice floe 14 feet thick; stopped to examine it for a day, and as the pressure of the ice increased every hour considerably, without evident reason for this, I thought that we were too much to west, and that this was not the route for the ice breaker. After considering the matter, I came to the conclusion that in this locality pressure of the ice should be almost constant; the direction of the movement of the ice to the north of Spitzbergen is west-southwest, while on the western part of it it is southwest by south. There ought to be something that compels the whole body of ice to change its direction almost suddenly as much as three points. I presume that this change is due to the position of the Greenland coast, which stops the westerly progress of the ice. Owing to this a heavy pressure is accumulated on the northeastern side of Greenland, which interferes with the drift of the ice of that locality to the south. The ice remains there for many years, growing in thickness. Is it not due to this that Nares met on the coast of Greenland heavy ice, to which he has given the name palæocrystic? Certainly this is only my conjecture, but it looks at present rather probable. If it is so, this locality is not a place through which one would advance fairly ahead, even with the powerful ice breaker.

The pressure of ice was so considerable and the ice so heavy that it took me four hours to make 2 miles to the south. After this the ice was less thick, and we went at our usual rate, making 2½ miles an hour; later on the ice became still easier, which allowed us to go more quickly. After we covered about 60 miles we found open water, followed the boundary of it, and entered the ice again to the north of Seven Islands. In this place we had much of the hummocky ice, but that did not stop the progress of the ship.

On August 14 the weather was very clear, no clouds on the horizon, and the air very transparent. We saw to the east of us a land which is not marked on the map. We did not see that land directly. We saw it only by the refraction of the air, but we saw it distinctly from 6 o'clock in the evening to 11 o'clock the next morning, and took the bearings of it. It could not be Franz Josef Land, the nearest part of which was at that time at a distance of 260 miles from us. Neither was it Gillies Land, which was at the distance of 160 miles. We believe we saw undiscovered land, and if we estimate the distance to be 100 miles, that land should be no less than 60 miles long.

On August 16 we directed our course to the south, and we saw four complete table-shaped icebergs from 40 to 60 feet high, and many débris of icebergs; one of them was completely covered with moraines. We picked up some stones from it. A little piece of metal was found between the stones, and there are signs of metal in the other stones. It has not yet been examined by any geologist, so that I can not say much about their nature. Neither can I state from what land they come. Maybe they come from the land which we supposed we had seen.

During the whole voyage we had an opportunity of studying the nature of the polar ice, the *Yermak*, with her powerful cranes and winches, offering a very efficient means for this. Our usual way was to cut a piece of ice, or to find one of a suitable size, and to lift it on deck. The pieces which were found in the water were liable to melt, although the water had a temperature of 29.3° F. This melting affected the superficial part of the block of ice, and the interior of it was as strong as might be. A block of ice being brought on deck, holes were drilled into it at different depths, and the thermometer introduced. Generally the temperature of the ice at that late season, at the surface, is not far from freezing point, and in the lower strata it corresponds to the temperature of sea water.

On one occasion we had a good chance of taking the temperature of an ice floe 14 feet thick; a piece of it, broken by the *Yermak*, was found floating on its side. We found that the temperature inside of it was 28.5° F., i. e. 0.5° below freezing point of sea water. I am not sure whether it shows that such thick blocks do not lose entirely during the summer their excess of cold received in winter.

After the temperature of the block of ice was taken we used to cut at different depths oblong pieces of a certain size, and by submerging them in water, study the specific gravity of the ice. Experiments were made with 26 samples, and they have shown that the floating part of the ice is within the limits of 6.5 per cent to 16.4 per cent, while the average is 12 per cent.

After experiments on the floating of the ice, oblong pieces were subjected to the trial of breaking. The strongest ice was found to be glacier ice, which required 180 pounds to break the oblongs. The weakest ice proved to be that from the floe, 14 feet thick, and required 63 pounds to break it; the average of the other ice shows that 110 pounds are required to break the same oblong. After this we melted the ice from different depths of the floe, and we tested the melting point. It proved to be very near to the freezing point of fresh water.

The exterior part of the ice in water is spongy, with canals and holes in it; it looks from the top like lace. The ice of this spongy part has the lowest melting point visible, from 31.3° to 30.6°. We subjected the sea ice to the influence of a current of salt water, 29.8 F., and found that ice melts in that temperature very easily. It is rather remarkable that ice melts in water the temperature of which is more than 2 degrees below its melting temperature.

After the melting point of the ice was determined, we measured the specific gravity of the liquefied ice; it was proved that this water contained generally very little salt indeed. Surface ice gave almost fresh water, but the ice at the bottom of the floe contained a little more salt, salinity varying from 0.01 to 0.69. The latter high salinity is obtained from the liquid ice of the spongy part of the floe.

Direct measurement of the ice floes has shown that the ice ridges have generally the height of 10 to 14 feet. It is not unusual to meet an ice ridge 16 feet high. One separate ice ridge was 22 feet high, while on one occasion we saw a detached piece projecting something about 6 fathoms. We did not reach it, and consequently could not measure it, so that this last figure is estimated by eye.

There is no difficulty in measuring the superficial part of the ice, but it is not so easy to obtain a proper knowledge of the depth to which the ice ridges extend below the water line. The direct boring of the ice gives good figures. We had an ordinary boring machine, but that did not answer the purpose well enough, because the progress of boring was rather slow. Then we arranged a steam jet, which melted a hole in the ice, and answered the purpose admirably; but unfortunately we were short of pipes, and could not reach the lowest part of the ridges. The direct boring showed the thickness of ice and water layers, or spaces in the direct vertical line. These are the figures:

First boring—
12 feet ice.
2 feet water.
3 feet ice.
2 feet water.
4 feet ice.
—
Total, 23 feet.

Second boring—
21 feet ice.
2 feet water.
3 feet ice.
—
Total, 26 feet.

Then we tried to pass under the ice ridges a float with Thomson's sounding tube attached to it. We put the float on one side of the ice floe and passed the rope around it to the other side. A little weight was generally attached at 1 fathom distance from the float. When the rope sank properly we pulled it to the other side of the floe. Sometimes all this maneuver was done with the boat and sometimes with the ship itself, her three propellers giving facility for such complicated maneuver. The float passed under the chain of ridges, but of course it did not get to the lowest part, which might project somewhere. Often the sounding tube has shown 4 to 5 fathoms' depth, but sometimes it has shown 7 fathoms. Separate pieces may project below to the depth of 8 or 9 fathoms, so that the ice floe may touch the ground at that depth, but probably will not properly settle itself until the depth of 5 or 6 fathoms is reached.

Hydrological observations consisted in determining the specific gravity of water at different depths. Below I give the specific gravity and temperature of water at two stations, one being on a parallel of the north part of Spitzbergen, another on the parallel of North Cape:

Station No. 31, August 20. 79° 41′ N., 40° 58′ E.			Station No. 34, August 23. 73° 22′ N., 10° 20′ E.		
Depth.	Temperature.	$S.\frac{17.5}{17.5}$	Depth.	Temperature.	$S.\frac{17.5}{17.5}$
Fathoms.	°*F.*		*Fathoms.*	°*F.*	
0	31.6	1.0248	0	41.6	1.0270
14	36.5	1.0265	27	40.0	1.0270
27	33.3		54	38.6	1.0270
33	35.6	1.0268	437	31.9	1.0270
38	36.4	1.0270	820	30.2	1.0270
437	31.6	1.0268	1,093	30.1	1.0271
820	30.4	1.0269			
1,093	30.1	1.0269			
1,367	30.1	1.0270			

On examining the figures of both stations, one can not fail remarking that from the depth of 100 fathoms to the bottom the temperature and specific gravity of water are almost the same. In the upper strata of station No. 34 the water on the surface is the same as at the bottom, visible gulf stream water; while at station No. 31 the water of the upper strata is much influenced by fresh water from ice and precipitations. It is remarkable that on that station the superficial water is cold; then comes a warm layer, then again cold, then warm and cold again.

Cold water at the lower strata at both stations has a temperature of 30°. Such a low temperature is not met in the Atlantic to the south of the Thomson ridge. The water acquires such a low temperature somewhere in these localities; it can not be in the polar sea, notwithstanding its excessive cold, because the upper strata there have less density. I have discussed this question with Sir John Murray. He thinks that the cold layer of this region is supplied from the top water being cooled during the winter somewhere close to Spitzbergen, or to the south of it, where no water of less density interferes with the upper layers descending to the bottom, when it is properly cooled by the winter cold. I perfectly coincide with the opinion of the distinguished oceanographer, and I am of opinion that cold water must settle down the slope of the bottom close to Spitzbergen.

There is no voyager in the polar regions who has not his own story of bear shooting. I could not sacrifice time in that sport, but there is such an abundance of polar bears that one can not avoid having a shot at them. Fresh traces of the white bear are seen on almost every other ice floe. Generally the track goes from one end of the floe to the other, and it looks as if the bear on his way goes straight, whether on water or a floe of ice. The bear usually makes a hole in the snow, and then lies down in it, so that you can not see him from a short distance. When a ship passes he jumps out at once from his hole, and were it not for this one would pass him by unnoticed.

The moment we entered the ice in June we saw two bears, but we were very busy at that time with the study of the ice, so that we let them go their own way. When we came next into the ice in August we saw some bears almost every day. One bear was upon the floe when we approached. Our sportsman wounded him, but the bear escaped to the other end of the floe, and swam over the lane. By that time the *Yermak* approached the place where the bear was, and it was shot dead by a bullet from the forecastle of the ship. We stayed a quarter of an hour to get him on board. On another occasion three bears approached the ship at 4 o'clock in the morning. Afterwards they proved to be a she bear with her cub, and a he bear. The watchman roused the sportsman, who at once pursued the bears. The cub was wounded first, in the leg, and it was most pathetic to see the mother bear help her baby to get over the ridges. Another bullet killed the cub. The mother bear, imagining that it was the he bear that had killed the baby, rushed violently upon the he bear, and ripped up his skin for more than a foot in length. This gave to our sportsman the chance to approach and finish with both bears.

The most interesting part of the experiment is the behavior of the ship herself in the ice; the question whether or not the steel ice breaker can break polar ice and stand its pressure. Experiments in the Baltic have shown that a great deal of power is required to propel the ship through the ice. Ice ridges in deep water, in the Baltic, never attain any considerable height, but the ice is difficult to pass through; and it happens that the ice field, which is no higher than 1 or 2 feet, requires more power than the *Yermak* can supply. In these cases we were obliged to move the ship astern, and charge at full speed, gaining sometimes less than the half-length of the ship at a charge. The fact is that the Baltic ice, being composed of pieces no more than 2 to 3 feet thick, gives a very great skin resistance to the ship. This was so to such an extent that other ships following the *Yermak* in the canal opened by her, on some occasions, could scarcely proceed with full speed.

It is quite another proceeding, breaking the polar ice. In some places of the Baltic the ice field is uninterrupted from one shore to another. In the arctic seas the ice is broken. Floes of ice might be several miles or several fathoms in length. Between ice floes are the lanes, which are very irregular. Sometimes ice floes are pressed against each other and sometimes not. When the ice is not pressed, the progress of the ship is very easy. Floes of ice even a mile long move away and give passage to the ship. The sharp, projecting angles of the floes break very easily, and sometimes it is preferable to shorten the way by cutting a floe right through. Thick polar ice looks very heavy and strong, and when walking on it one can not imagine that such a heavy thing could be broken. But the fact is that even ice 14 feet thick cracks when charged at by the ship, provided there is room to remove broken parts.

The lower part of the polar floe has constantly, more or less, the same temperature, while the temperature of the surface varies with the temperature of the air, which sometimes produces the cracks and sometimes prepares the ice for cracking. The moment the ship charges the ice it cracks at the place at which it might crack in half an hour itself with another change of temperature of a degree or so, or with the beginning of pressure. The big floe cracks more easily than the small floe, which sometimes is pushed by the ship and goes in front until it manages somehow to pass on one side of the ship or the other.

Fields of hummocky ice are liable to crack even more than fields of plain ice. In charging that ice the ship's bow rises to 9 feet; then the field cracks, the ship falls down and goes ahead, moving aside the débris of the ice field. It is a most exciting scene to see some of the big pieces of ice falling down into the water and the others coming to the surface from a great depth, every detached piece trying to find a new position, while the ship itself, being always pushed ahead by her machinery, gradually advances, maybe rises again, and gives another crack to the field ice. We took some cinematograph pictures, which show how much the ship lifts herself up in the ice, and that gives us means of calculating what weight is applied to crack the floe of ice. If the ice is in the period of pressure, progress is not so easy. On one occasion it took me four hours to make 2 miles, while usually the ship went, by zigzags, with a speed of 3½ knots, making good 2½ knots an hour.

There is a great difference in ice-breaking in the Baltic Sea and the polar regions. Hummocks in the Baltic Sea are never high above the level, but sometimes they are very deep. According to our measurement, they go down to as much as 20 feet. On one occasion we measured 27 feet down and 6 feet up, the total being 33 feet. Such hummocks are composed of pieces 1 to 3 feet thick. Many hummocks are formed at the time when ice is moved by the swell; the result of this is that every piece of ice finds its best position, and the whole hummock is very compact. When the ship charges into it, it does not always form long cracks, but breaks under the ship, producing no heavy effect upon her skin. When the ship passes half of its length in such a floe, she touches so many fragments of ice that they stop the progress of the ship by the friction and the pressure upon the skin of the fore part of the ship. When the ship stops, there is no other way than to go back and charge again. This time, before the bow of the ship touches the solid ice it has to run through 100 feet or so of broken ice; that diminishes very much the speed of the ship, which on a second charge may make a very little headway. It happens sometimes that after the ship stops going ahead it won't go back, and it takes half an hour, until by reversing the engines ahead and astern one can get the ship out of this disagreeable standstill position. From time to time it happens that one has to get the use of an ice anchor to move the ship astern. Nothing like this happens in the polar ice, which breaks into big pieces, and consequently there is not so much skin resistance. The moment you stop your engines the ship goes back herself, and there will be no fragments left which could stop her progress when she charges the second time. For this reason the second charge will be almost as efficient as the first, and we never wanted an ice cage to move the ship in the polar region.

Fresh-water ice in the Baltic is stronger than the salt-water ice in the Arctic Sea, but, owing to the dimensions of the pieces of the ice, the ship never receives such tremendous local blows in the Baltic Sea as in the polar region. The general conclusion is that in the Baltic the force of the engine is required, while in the Arctic the strength of the construction is the main thing to pay attention to.

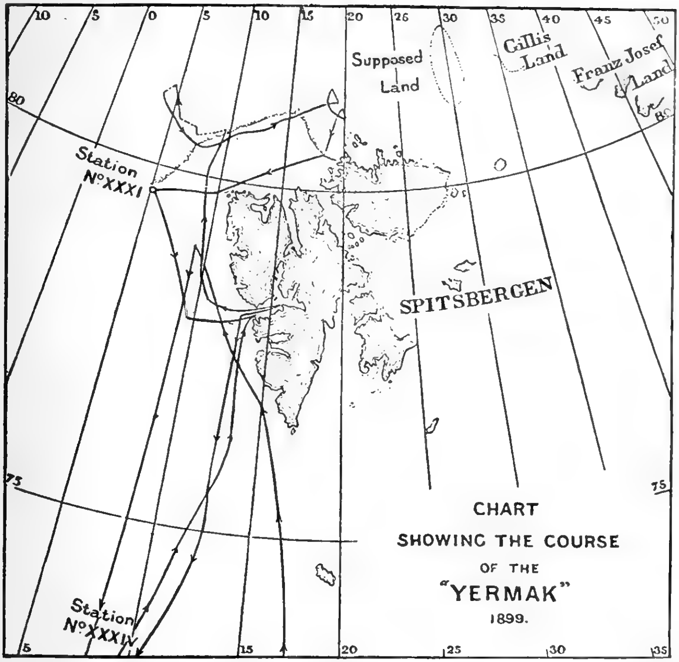
It is most interesting to decide the question whether my idea of exploring the polar regions by means of ice breakers is sound or not; whether in future explorers of the Arctic should stick to their sledges and dogs, or trust themselves to the drifting ships of Dr. Nansen, or embark upon the strong ice breakers. It looks as if the voyage on the ice breaker is the most expensive of the three, but it saves time, which, if properly calculated, is always money. If we come to the conclusion that the ice breaker is to be used for the exploration of the Arctic, then comes the question, What sort of ice breaker is good for that purpose? Shall we repeat the *Yermak*, or shall we give to the new ice breaker another feature, basing ourselves upon the lesson given us by the experiments of the *Yermak* in the polar ice? Surely the *Yermak* is not the last work of science in that direction. The forward propeller was very much praised in America, and proved to be useful in the Baltic. But when we first entered the ice in June last, I felt at once that the fore propeller had to be removed, which was done on my returning to Newcastle. No forward propeller could stand the charges of the ice breaker into the polar ice; and if it does so, it stops the progress of the ship. Of course, the *Yermak* is meant for double service; for the Baltic the forward propeller is useful, and for the Arctic it is objectionable. We have either to sacrifice one or the other; but if a special ice breaker has to be built for the Arctic it ought to be without forward propeller.

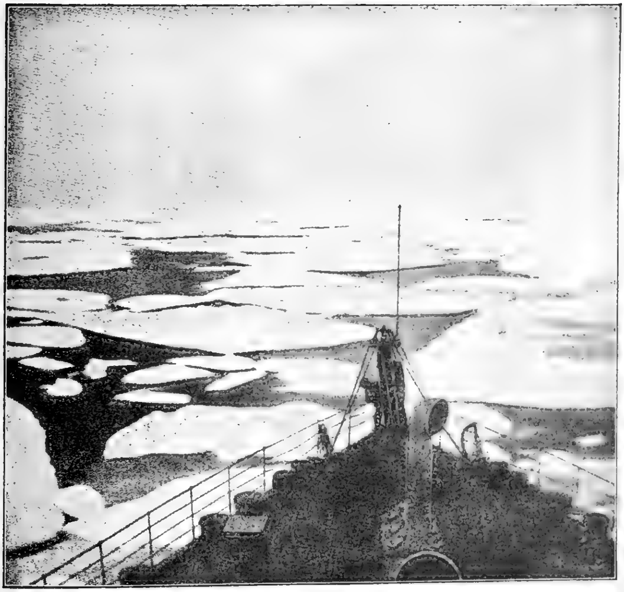
With regard to the strength of the ship, it is not a question of the weight of material; it is a question of knowledge and experience, and I believe that Messrs. Armstrong, Whitworth & Co. have learned very much since our last trial in the polar ice. One can not make a mistake in building a ship too strong. The *Yermak* had to be improved in that respect after the first trial, and we have to do something more now. Had it not been for this I would not have returned without penetrating farther on, in order to study that unknown region a little more.

The angle of the stem, 70° from the vertical line, proved to be a good one; 20° for the sides of the ship is also not bad, but it should run a bit higher than on board the *Yermak*, because the ship receives with her sides tremendous blows; 25° would be still more profitable. With such a shape of ship one would expect that the ship would roll heavily at sea. I did not dare to give to the *Yermak* any bilge keel, but I think it would do no harm to the ice-breaking qualities if the ship was supplied with two short bilge keels on the last third of the length of the ship; it would improve, somehow, her rolling quality; also a big rolling chamber would be useful.

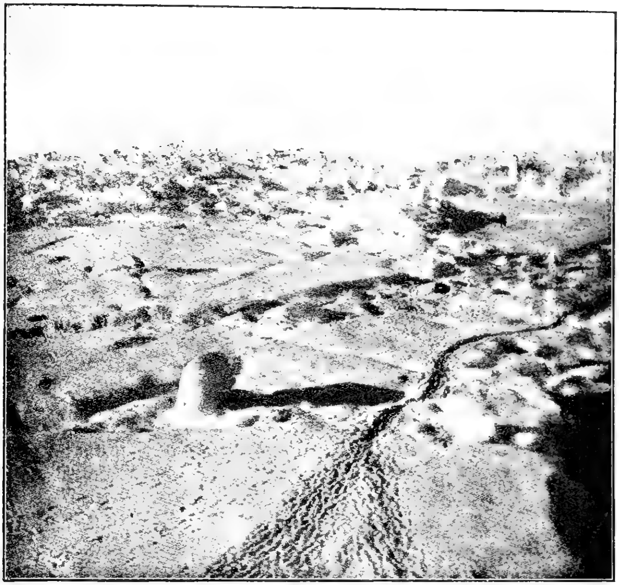
The proportion of the *Yermak* is 1 to 4¼; it is such because the ship has to enter the port of St. Petersburg. For the polar ice breaker finer lines would be better, but finer lines increase the weight of the ship. I believe 1 to 5 would be a good proportion.

The size of the ship depends very much on the power required and the quantity of coal supply. The bigger the ship the more powerful will be the engines and the greater the supply of coals. During our work in the Arctic we seldom used our full power; the ship progressed fairly well with the engines working slow. However, sometimes it happened, during the pressure of the ice, that full power was required. In such a case a ship with weak engines has to wait, but it should not be more than a few hours. The progress of the ice breaker with smaller engines will not be so quick; anyhow, it will be progress. I may say, the less power you have the more patience you want in going through the polar ices. The *Fram* had 200 horsepower; it was not enough for a good ice breaker; but I believe 2,500 horsepower will be sufficient for fairly good progress through the ice.





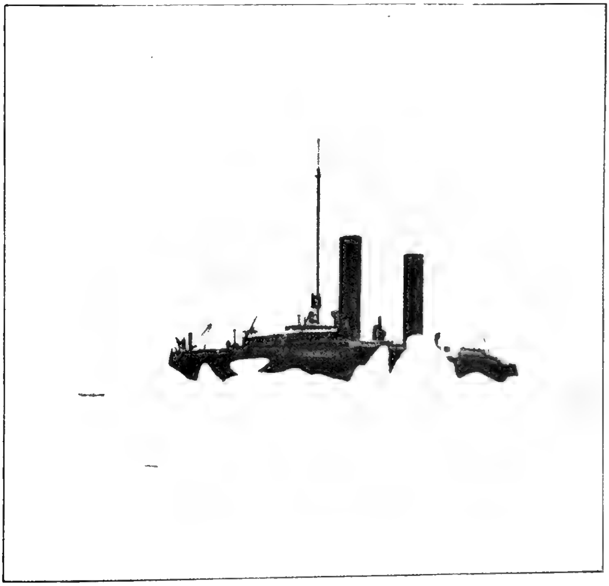
GOING THROUGH EASY ICE.



HUMMOCKY FLOE.

MORENAS ON THE ICEBERG.

YERMAK IN HEAVY ICE.



YERMAK CHARGING THE ICE.

The distance that one can go through the ice will depend upon the quantity of fuel, and as liquid fuel is more efficient than coal, it should be accepted for the polar ice breaker. That fuel is easily put into any compartment of the ship, so that on entering the ice one can have as much of that fuel as the ice belt and the shape of the vessel allows. Liquid fuel has another advantage particularly applicable to ice breaking, where the speed of the engine is changed so often. With the liquid fuel you stop burning instantaneously, while with the coal you burn it unnecessarily every time you unexpectedly reduce your full speed to a dead slow. Liquid fuel is easily pumped from one part of the ship to the other, and can be used for trimming and heeling purposes.

All these deductions are preliminary. I have to think over them, and maybe more detailed study of the material we collected will force me to make a slight modification of what I have stated in this paper. But there will be no modification in my idea that the exploration of the Arctic and Antarctic ought to be done with the help of the polar ice breakers.

THE GROWTH OF BIOLOGY IN THE NINETEENTH CENTURY.[1]

Address before Congress of Scientists at Aachen, September 17, 1900,

By Oscar Hertwig,

Director of the Anatomical and Biological Institute of the University of Berlin.

The first of the series of addresses which, upon the close of the century, are to give you a short review of the acquisitions of the natural sciences, treated of a department in which the successes of the scientist have been particularly prominent; for the acquaintance with the forces of nature, which the chemist and physicist have earned by investigation in their laboratories, is the starting point for an expert mastery of nature that has reconstructed the life of civilized peoples from its foundation. From unpromising chemical and physical discoveries have arisen numerous giant industries, the basis of a commerce on an even more magnificent scale, and various technical contrivances by which men have more and more subjected space and time to their will, flitting by the force of steam, without fatigue, over wide stretches of land, or interchanging their ideas with the speed of lightning over the ocean.

The honorable task which has fallen to my lot is to report upon the development of biology during the nineteenth century. That science has no such glittering successes to show as those I have mentioned; yet I think I may venture to assert that the knowledge of nature which human sagacity has won even in the realm of biology is not inferior to the discoveries and inventions of the chemico-physical sciences in general scientific importance and in fruitfulness for human civilization. The insight into the complicated laws of nature that govern organisms as well as inorganic bodies, the inquiry into their structure, their origin, their vital processes, their relations to one another and to the cosmos, teaches us to subject the world of living creatures also to the domination

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[1] Translation of Die Entwicklung der Biologie im 19 Jahrhundert. Vortrag auf der Versammlung deutscher Naturforscher zu Aachen am 17 September, 1900, gehalten von Oscar Hertwig, Director des anatomisch-biologischen Instituts der Berliner Universität. Jena. Verlag von Gustav Fischer, 1900.

of our mind, thereby to make them serviceable to our welfare in countless ways, or where they confront us as hostile powers to defend ourselves from them by hygienic protective measures. But what is much more important, biology enlightens us concerning our own human nature, both in its corporeal and in its spiritual aspects, and consequently leads to a greater mastery over ourselves; and in accordance with the progress of that knowledge biology influences even our religious, moral, and social ideas, and thereby arouses world-moving forces which have a no less transforming effect on the conduct of our life than does the expert mastery over inanimate nature, made possible by physics and chemistry.

The endless realm of biology is much more extensive than the chemico-physical sciences. For that reason, in the brief time during which I can venture to beg your attention I can only give a summary review of the development of the science during the nineteenth century, and can only refer to those particular directions in which our biological knowledge has made its principal progress.

A short definition can scarcely express correctly what a living being is, or what life is. It can only be said that life depends upon a special, peculiar organization of matter, and that with this organization are connected special functions (Verrichtungen oder Functionen) which are never met with in lifeless nature. The particular branches of science which relate to the study of animals and plants are, therefore, commonly divided into two groups, the anatomical and physiological sciences; that is to say, into those which deal with the structure or organization of the being and those which relate to its functions and its life processes.

In both directions our knowledge has been infinitely extended during the century. While the sixteenth and seventeenth centuries brought the great anatomists, an Eustachius, a Fallopia, a Vesalius, who, with knife and scissors, opened for us a glimpse into the numerous organs of the human body, biology in the nineteenth century has achieved its greatest victory in the province of microscopic anatomy. Equipped with the compound microscope, that wonderful instrument which eminent opticians have brought to the highest degree of efficiency, the anatomists were now in a position to discover a new and previously unsuspected world of life.

I believe, without hesitation, that I must indicate as one of the greatest acquisitions of biology during the nineteenth century the discovery that plants and animals are built up of cells, or, speaking in general terms, of innumerable minute elementary organisms. By the joint labors of famous biologists—I will name only Purkinje, Schleiden and Schwann, Hugo von Mohl, Nägeli, Remak, Kölliker and Virchow, Brücke, Cohn, and Max Schultze—our knowledge of the organization of living substance has been infinitely broadened and deepened. Anatomy and physiology have received a solid foundation in the theory of cells and of protoplasm, just as chemistry has in the doctrine of atoms and molecules.

A series of very important ideas has arisen with the cell theory. If plants and animals represent in a certain way colonies or states of socially connected elementary living beings, vital processes are nothing more than highly complicated resultants of numerous elementary processes which are performed in the cells. Thus it was suggested to draw parallels and to institute instructive comparisons, on the one hand, between the individual members of a human state and the adjustments which a state necessitates, and, on the other hand, between the structure and the life of the vegetable and animal body. The law of the division of labor and of differentiation, which in human society causes separation into special professional classes and the immense diversity of social employments, was rightly adduced by Milne-Edwards, by Spencer, and by many others to illustrate the building up of the vegetable and animal body from its organs and tissues. With Lionel Beale and Max Schultze we learned to distinguish in histology between a formative substance, the protoplasm of the cells, and the product of their formation or work, and recognized that the various cells as they assumed in the service of the whole organism different functions or work, according to time and place and their relations to one another, became correspondingly diversified in their intimate structure, and that in this way the various tissues and organs came into existence.

The scientific elaboration of the theory of cells and tissues has occupied many naturalists for several generations, and they have erected the stately palace of the microscopic anatomy of plants and animals. Yet even here many important questions await solution, especially that of the finer structure of the cell-nucleus and of protoplasm, and the question of the microscopic structure of the nervous system and of the organs of sense, concerning which almost every year still brings us new investigations and new discoveries, sometimes of great importance.

With the aid of the compound microscope biological research has in the passing century opened to our inspection a second new and sovereign world of life, the world of the simplest unicellular organisms, which were introduced into classification by many investigators as an intermediate kingdom between plants and animals—the protista. Great was the wonder, in the middle of our century, when Ehrenberg discovered that whole geological formations originate from (erdschichten) very minute organisms, often hardly visible to the naked eye, which grow in fresh water and in the sea in immense numbers. For when, at death, their soft protoplasmal bodies decompose, their hard shells and skeletons of carbonate of lime or of silica still remain, and sinking by their weight to the bottom produce, in thousands of years, in spite of their small size, yet in virtue of their inconceivable multitude, strata many meters thick. The chalk cliffs on the coasts of Rügen and of England are built up of the remains of foraminifera; many islands in the South Sea, of the wonderful siliceous framework of radiolaria, and strata, such as the diatomaceous earth of Bilina, of the siliceous shells of diatoms.

But still more important than these highly interesting facts for our general knowledge of nature was a second series of discoveries which I would place by the side of the cell theory as a second capital achievement of the century in the department of biology. Minute organisms are recognized as the cause of widely distributed processes of putrefaction, of fermentation, and of very numerous diseases of plants and of animals. They are unicellular algæ, fungi, bacteria, and allied micro-organisms.

Three great investigators have here been the pioneers—in the botanical department, de Bary, who laid the foundation for the study of diseases of plants by the elaboration of suitable methods of observation and processes of cultivation; in the bacteriological department, Pasteur and Robert Koch. The great French investigator, equally distinguished as a chemist and as a biologist, and particularly Robert Koch, have by their experimental methods—among which pure cultures, artificial nutriment (Nährböden), the gelatin processes, and transfer by inoculation, stand at the head—afforded ways and means which we must thank for an immense enrichment of our knowledge.

Again, in the short span of two or three decades, an extensive department of science has been established—I mean bacteriology. For it is the characteristic phenomenon of our age, with its greatly increased interest in science, with its more perfect organization of expert work (gelehsten arbeit), with its numerous scientific institutions, with its enlightened and accelerated intercommunication of ideas by journals and by the daily press, that if a new mark is set up, and if the way to its attainment—the scientific method—is found, then everywhere the forces of work are roused to feverish activity as in no earlier time. How quickly were the first abortive experiments followed by a knowledge of microbes. The exciting agents of anthrax, of septicemia and pyemia, of erysipelas, of typhus, of intermittent fever and of cholera, of tuberculosis, of malaria, and of many other infectious diseases of men and of animals, down to insects and worms, were discovered, and their life histories studied.

It is a grand thing to enrich our stock of knowledge by new discoveries; yet it may be not less important and serviceable to refute and eliminate errors, and especially the errors which infest science itself. The less men knew in the past of the vital process the more ready they were to accept as an established fact the hypothesis of spontaneous generation (Urzeugung)—that is to say, the assumption that the simplest living beings take their origin direct from lifeless nature. Just as in the eighteenth century intestinal worms and infusoria, also formerly called infusion-animalculæ (Aufgussthierchen), were supposed to arise by "equivocal generation," so at a later date bacteria and allied microbes, because they seemed so very small and simple, and so suddenly invaded liquids without anybody's knowing whence they came, were supposed to be so formed. It was not one of the smallest services which Pasteur rendered, that he irrefutably proved, by scientific methods, that for microbes, too, the saying is fulfilled, "Omne vivum e vivo," life comes only from life. By Pasteur's experiments we know that the germs of those organisms are everywhere more or less abundantly distributed in water, air, and earth.

In the doctrine of cells, too, in its first form, the idea of spontaneous generation made a pernicious nest, for, according to the view of Scheiden and Schwann, new cells arise in the bodies of animals and plants by a sort of crystallization from a nutritive solution, either within or without mother cells. The truth that the increase takes place solely by propagation by division was first made out by wearisome labor by the admirable investigations of Mohl and Nägeli, of Remak, Kölliker, and Virchow, and many other students, and raised to the rank of a universal biological law: "Omnis cellula e cellula."

It may be broadly said that, in spite of all the progress of science, the chasm between living and lifeless nature, instead of gradually closing up, has, on the contrary, become deeper and wider. More thorough study, aided by philosophical intuition, teaches year by year more distinctly that the cell, that elementary bed rock of living nature, is far from being a peculiar chemical giant molecule, or living albumen, and as such destined to become the subject of the chemistry of the future. The cell is itself an organism, compounded from numerous still smaller vital units. They are of various chemical composition, and are bound together through relations to the vital process of the cells unknown to us. Here lies hidden a world of minute life for the investigation of which the power of our microscopes and usual methods of research fall short, but which, we will hope, a biology of the future, with more perfect instruments and methods, may attain.

A beginning has been made by the elaboration of the method of staining, which we may expect to be extraordinarily perfected and its powers to be greatly increased. To this we must add the insight which the investigations of Bütschli, Strasburger, Flemming, van Beneden, and many others have afforded of the facts (vorgang) of the division of nuclei and cells. In karyokinesis we see how, at certain times, minute parts in the cell of diverse chemical nature, such as centrosomes, spindle filaments, chromosomes, nucleoles, and protoplasm tracts are distinguishable, and how, impelled by enigmatical forces, they arrange themselves in a sequence of complicated figures, and so distribute themselves to two "daughter" organisms.

But the most impressive argument for the doctrine that the cell itself must, in its turn, be a highly complex organism is, above all, the part it plays in the developmental process of higher plants and animals, for the cells of egg and seed, as Nägeli has explained in a philosophical manner, are the vehicles of the numberless properties by which the different species of organisms are distinguished. They therefore consist of hereditary masses or idioplasm, which, in order to include the inherited properties which are destined to become manifest in growth, must be a highly organized body.

With this, I come to the third great advance which biology has effected in the nineteenth century. More than previous ages, our century has been dominated by the idea of development. It has made itself felt as a working leaven in many departments of knowledge, philosophy, history, philology, sociology, and geology, but nowhere more than in biology. Yet the living organism is the only natural object which puts before our eyes, in a short space of time, a complete cycle of development, from the fecundated egg to the perfect creation again productive of new life.

On closer examination the question of the development of the organism embraces two different questions: First, that of the development of the individual—that is, the cycle of phenomena through which it runs, starting from the egg until its natural death; and, secondly, the question as to how so extraordinarily complicated a product as we have found the vegetable or animal organism to be arose in a natural way in the course of the earth's history. Ontogeny and phylogeny, to avail ourselves of a pair of terms introduced by Haeckel, are the two fields of research into which the doctrine of development of organisms is divided.

Ontogeny alone is subject to direct scientific investigation. From the fertilized egg on it is possible, by the choice of suitable plants and animals, to follow their development step by step from one stage to the next. Here again the microscope has been the instrument with the help of which we have penetrated deeply into ontogeny and have set forth the universal laws of formation. Since the days of Pander and Carl Ernst von Baer, who has been called the "father of the history of development" on account of his immortal services, thanks to a great roll of German, French, English, Russian, and Italian embryologists, there has been erected a comprehensive, excellent, lordly, well-joined, systematic history of development. In details many processes have yet to be examined more nicely; but, on the whole, the essence of individual development has been explained upon its morphological side, and we have a right to be proud of the insight into it which we have gained, especially when we recall how the greatest men of science and philosophers of former centuries—Haller, Leibnitz, Cuvier—were wrecked on the problem of development; how they stood impotent before it with their methods of research.

That every animal, man included, is at the beginning of his life temporarily a single cell; that this cell multiplies by frequently repeated divisions; that the cells arrange themselves into germinal layers from which again the single organs take their origin, and that it is by the association of the cell communities, as they multiply, after many metamorphoses, that the perfect creature is formed, are facts of the correctness of which everybody can easily convince himself. They are secure, permanent acquisitions of science.

With the second question, on the other hand, we pass to the sphere of hypothesis. How did the organisms that are living to-day arise in the course of the earth's history? Certainly an investigator well schooled in philosophy will consider it to be a universal truth that the organisms which to-day people the earth did not in bygone geological ages exist in their present forms, but they, too, must have gone through a process of development, beginning with the simplest forms, which Haeckel has distinguished from the ontogenetical process by terming it phylogenetical. The investigator will come to this conclusion by connecting different departments of biology. He will especially rely upon the facts of individual development, which actually teach a becoming of the complicated from the simpler. He will further appeal to comparative anatomy, upon that philosophical science whose erection has been brought in our century to high perfection by Cuvier and Meckel, by Johannes Müller and Gegenbaur.

But try to fully portray in detail in what special form a species of animals of our day lived in the hoary antiquity, and the ground of experience vanishes beneath you, for of the innumerable milliards of creatures which lived in former geological periods—periods whose duration is estimated in millions of years—only scanty remains of skeletons have in exceptional cases been preserved in a fossil condition. Of course from them we can gather but a very incomplete and hypothetical idea of the soft bodies to which they once belonged. Furthermore, it remains in every case undecided whether the descendants of the ancient creature whose sparse remains we study did not die out altogether, so that he can not be claimed as the ancestor of any living form whatever.

Twice in our century has the question of descent deeply stirred both scientists and laymen and injected a powerful ferment into the world of ideas. Brightly shine down upon us from history the opposite names of Lamarck and Darwin. Lamarck, the great French zoölogist, wrote at the beginning of our century, at the time of the German and French philosophy of nature, his famous Philosophie Zoologique, a monument of freer philosophical consideration of the world of organisms. In 1859 Charles Darwin published his epoch-making work upon the origin of species, a work distinguished for the collection and sifting of a great and previously little-noticed mass of facts, and by being crammed with important new points of view. In particular much light was thrown by Darwin upon the relations of organisms to one another and to environing nature, a subject which had previously been neglected and even now is little understood, notwithstanding the partial insight into it which that great genius has afforded.

More fortunate than his forerunner, whose merit was only first recognized by posterity, Darwin saw his doctrine fall upon better prepared soil, so that it produced a scientific movement sustained by enthusiasm and adopting his name, Darwinism. He had the good luck to be supplemented by a powerful advocate, Haeckel, who in knowledge of anatomy and of the history of development far surpassed him. Men now believed that the secret of how new organic species arise was at last out; that the riddle of the "true causes of forms" had been guessed, and that the theory of selection furnished the elucidation of the theory of descent. "Struggle for existence," "survival of the fittest," "natural selection," were the formulæ by which the organic empire was to be laid open. Adherents and opponents to the new doctrine appeared. Hither and thither waged the battle with a vehemence which scientific hypotheses seldom inspire. Darwinists, Ultradarwinists, Antidarwinists, Neodarwinists, Haeckelians, and Weismannists mingled in the fray. Weismann, going beyond Darwin, published The Omnipotence of Natural Selection; Herbert Spencer hurled at him with The Inadequacy of Natural Selection.

This sort of thing is comprehensible in politics, but how shall we explain such a remarkable turmoil about a scientific question? It seems to me that not the least of the reasons was that the formulæ of explanation, "struggle for existence," "survival of the fittest," "selection," are very vague expressions, which only gain scientific value by the mode in which they are applied in the concrete case. Why has the term "struggle for existence" not been brought down to application? It has become a standing and favorite form of words in writings upon national economy and politics; and there it is excusable. But it begins to be less so when, at the Darwinian flood tide, Du Prel would use it as a formula to explain the motions of the heavenly bodies. With too general terms single cases can not be explained, or a mere shadow of an explanation is given, while the true causal connection remains as much in the dark as before. Now, the problem of scientific research is to make out the precise cause of an observed effect, or, more correctly, since nothing happens from a single cause, its different causes.

But surely the origin of the organic world by natural causes is an extraordinarily intricate and difficult problem. It is as little to be solved by a magical formula as all diseases are to be cured by one medicine. While Weismann was announcing the "omnipotence of natural selection," he saw himself forced to the confession, "We can usually not prove that any given adaptation is due to natural selection." Now, this is as much as to say: In truth, we know nothing about the complex of causes which has produced the particular phenomenon. "Inadequacy of natural selection" therefore opposes itself, with Spencer.

In this scientific strife with which our century closes, the doctrine of development is to be distinguished from the selection theory. The two stand upon very different ground. For we may say, with Huxley, "If the Darwinian hypothesis were swept away, evolution would still stand where it was." In it we possess a permanent acquisition of our century; one of its greatest, and resting upon facts.

With the discussion of the doctrine of development and the theory of selection, we have already made a step into the realm of physiology. But every division of a science into special departments, including that of biology into anatomy and physiology, is artificial and scarcely capable of being strictly carried out. The construction and the action of a part, or its structure and its function, are intimately connected; so much so, indeed, that neither can truly be understood without studying the other.

Observation alone will afford a very insufficient insight into the mode of working of a particular organ, and in many cases none at all. In order to obtain an answer to the question, What is an organ for (was leistet ein organ)? the physiologist has to avail himself of the most various aids, by which alone he can draw any conclusion from what he has observed; and what the microscope is for the anatomist, that for the physiologist is systematically conducted experimentation, scientific investigation of vegetable and animal organisms.

By phytophysiological experiments, Sachs, Pfeffer, and many other trained experimenters have enlightened us concerning the geotropism and heliotropism of plants, concerning phototaxis, chemotaxis, and similar interesting phenomena. Especially experimental physiology has established in how high a measure plants in all their functions, even in their formation, are dependent upon external factors.

Animal experiments can be conducted in various ways. Against one kind, termed vivisection, which involves slighter or more severe surgical operations, an obstinate campaign has been conducted in general society, and here and there not without some success. It is surely an ill-placed sensibility. For what should all the suffering that the investigator inflicts upon the animal world, and which he takes pains humanely to reduce to a minimum by chloroform and morphine, signify in comparison with the infinitely greater and more numerous benefits suffering humanity enjoys from the medicinal art, which the animal experiment and the knowledge gained by it brings to greater effectiveness? Or what should the victims of science, so trifling in number, signify in comparison with the numberless and much more grievous sufferings which in the unalterable order of nature one animal often inflicts upon another, it may be in bestial cruelty, or in comparison with the pain which the human race endures from accidents and diseases of all kinds, or which men inflict upon one another in murderous wars?

People ought rather to be thankful that by experiments upon animals physiology has in the nineteenth century most successfully increased the the treasure of our knowledge. The section and excitation of the spinal roots brought us Bell's theorem. In the same way the physiology of the most various peripheral nerves was brought into existence, including that most important of all this series of doctrines, that of the action of the vagus nerves. Johannes Müller established the law of the the specific energy of the nerves of sense. Partial sections of the spinal cord and the study of the heightened and lowered degeneration thereby produced enabled us to get a view of the different nervous paths of conduction. Acute experimenters even succeeded in penetrating into the secrets of the functions of the brain by localized lesions, by removal or other destruction of particular parts of the brain, and in discovering in the spinal marrow a special center of breathing and vascular control, in particular places of the cortex, here a center of language, there a seeing tract, a hearing tract, or a feeling tract, etc.

Experiments upon animals have put many other departments of physiology within reach of the scientific understanding. The celebrated Harvey's doctrine was refined to a mechanics of the circulation of the blood when the velocity of the current, as well as its pressure in different parts of the system of tubes, had been accurately measured by ingenious devices. The study of the physiology of digestion and of metabolism was well begun by making fistulas into the stomach and intestines or by otherwise obtaining juices of the different glands, and these, once obtained, were made the subjects of further experiments to discover their functions in the process of digestion.

A still greater blessing for mankind has come from experiments upon animals in two other directions, which in the nineteenth century have been systematically prosecuted and which are intimately connected with practical medicine, but do not require vivisection. One direction is that of the study of the effects of chemical bodies upon the organism into which they are absorbed. The investigator ought first to ascertain by numerous systematically conducted experiments upon animals what effects in every part of the system chloroform and ether, morphine, cocaine, antipyrine, or powerful poisons such as atropin, belladonna, strychnine, curare, and numerous other chemicals which chemical manufacturers are throwing in constantly increasing profusion upon the market, produce in stronger and in weaker doses before he studies their application as medicines for this or that diseased condition of man.

Our materia medica has been greatly enriched in this way during the last half century, and the increase goes on yearly. I will here call to mind the new processes of cure first tested upon animals which are acquisitions of the latest dates: Koch's tuberculin, the diphtheria serum of Behring and Ehrlich, and the other different kinds of serum that have been proposed against lockjaw, the plague, and many diseases of animals, as well as Pasteur's peculiar method of treatment of hydrophobia.

In the second direction I mentioned I have in mind the study of that great host of maladies evoked by the invasion into the animal system of alien parasitic organisms as excitants of disease. Experiments upon animals have alone rendered possible that great triumphal march which the biological research of our century has traveled over, discovery treading on the heels of discovery. In order to acquaint themselves with the essence of the trichina disease, Leuckart and Virchow caused trichinous meat to be consumed by many animals selected for experiment, and in that way gained a knowledge of the history of development of the trichina and the mode in which, by its introduction into the body of the infected animal, it produces the different stages of the process of disease. Davaine and Koch cleared up the nature of anthrax by inoculating a healthy, susceptible animal with a tiny drop of blood from an animal suffering from anthrax, and in this simple way infected it so as to establish the development of the anthrax bacillus in all stages. The investigator pursues the same method in all cases, with erysipelas and septicemia, typhus, cholera, the plague, tuberculosis, malaria, and, in a word, all the infectious diseases which are produced by the lowest fungi, bacteria, sporozoa, and other kinds of parasites.

But the modern physiologist contemplates with yet greater pride than that which the results of those animal experiments awaken, the extraordinary success which his science has achieved in our century in two other great fields, those of biochemistry and biophysics.

Under the rule of the vitalistic doctrine the scientific doctrine rife at the beginning of our century was that the organic substances of which the bodies of plants and animals are built could only be produced by the peculiar vital forces of these organisms, so that destiny refused to the chemist the power of imitating any such substances by his insufficient methods.

One brilliant discovery by Wöhler at length shattered the vitalistic error, for he succeeded in producing artificially in his laboratory one of the peculiar products of the vital process of animals, namely, urea. Soon, in the rapid progress upon which organic chemistry now entered, the like was accomplished in many other cases, until now the audacious hope can be cherished that some day chemistry may perhaps even perform the synthesis of albumen, the most complex of all organic substances. Chemistry has, however, progressed further in the analysis than in the synthesis of these organic bodies from which the cells, tissues, and juices of plants and animals are built, having analytically investigated the carbohydrates, fats, albuminous bodies, and their numberless derivatives and products of decomposition. Thus has a physiological chemistry gradually been developed—a science rich in results, from which still more weighty disclosures are awaited in the future.

The chemical processes upon the normal course of which life depends were naturally in great measure opened up to us by the increased knowledge of organic substances. Pflüger's invention of the mercurial gas pump and other important apparatus and the improvement of chemico-physiological methods generally imparted a powerful upward impulse to the physiology of respiration, of the formation of blood, of assimilation and secretion; while extensive and laborious experimental investigations by Claude Bernard, Pettenkofer and Voit, Ludwig, Pflüger, Heidenhain, and many others successfully elucidated the digestion of albuminous bodies, fats, and carbohydrates and the functions performed by the salivary glands, stomach, liver, and pancreas.

Simultaneously with triumphantly raising its head in the chemical direction, physiology did the same thing in the physical direction. In its contest with vitalism, which held to the assumption of special vital forces as needed for the explanation of life, thus erecting a rigid party wall between the inorganic world and the empire of life, the highest principle of physiology came to be that organisms are subject to the universal laws of nature. Its guiding star was the law of the conservation of force, which was established by Robert Mayer and Helmholtz; while the highest goal of its research was the introduction of physico-mathematical methods into physiology, by which it should become possible, by the methods of weighing, measuring, and counting, to penetrate the essence of the vital process and to render exact account of the different modes of energy which are distinguished as mechanical, chemical, thermic, and electric.

Then broke the dawn of that glorious day when physiology was enriched by apparatus of the most varied description and instruments invented with great ingenuity. By means of the cymograph and the myograph it succeeded in exhibiting to the eye upon the smoked plate and in measuring with the greatest exactitude the minutest features of motions of living organs, of the wall of the heart and those of the blood vessels, as well as the motions of the muscles. Galvanometer, rheostat, and slide-induction apparatus, tangent galvanometer, became common in the armamentarium of every physiological institute in order that the electrical phenomena of muscular action and the velocity of nervous transmission might be investigated. The ophthalmoscope of Helmholtz and the laryngoscope of Czermak enabled the investigator to aid practical medicine by giant strides into the view of the interior of two important organs.

The improvement of the instrumental equipment of physiology has continued without cessation to the end of the century. Every new acquisition of physics is immediately made available to physiology and medicine. Thus the physician is already, immediately after Röntgen's epoch-making discovery, in condition to bring into clear view upon the photographic plate, by suitable application of the so-called X-rays, parts hidden in the depths of the human body and absolutely invisible to the eye, such as single sections of the skeleton.

So pioneer investigations of physiologists trained in physics—a Helmholtz and a Du Bois-Reymond, a Fechner, Weber, Ludwig, Brücke, and Pflüger—as upon another occasion I have in a few words summarily remarked, have in our century "created a special physics of the nerves and muscles, a physics of the organs of sense, a mechanics of the skeleton and organs of locomotion, a mechanics of respiration and circulation."

"The eye was explained as a camera obscura arranged according to the laws of optics; the ear as a physical apparatus arranged to bring the nerves to the perception of acoustic vibrations by means of suitable organic structures, vibrating membranes and rods, which, like the wires of a pianoforte, are tuned to the different notes. The larynx became a reed pipe, adapted to the production of tones in vibrations, the lungs serving as the bellows. The laws of filtration and osmosis were adduced for the explanation of absorption and secretion. By a composition of intricate apparatus called a calorimeter the physiologist now determined the amount of heat reckoned in calories produced in the course of a day by an animal body, and undertook the difficult task of striking a balance sheet of the animal transformation of energy, the animal body being debtor to nutriment of different kinds in so many calories of energy, while upon the credit side were summed up the amounts of energy which the body had given in the form of heat produced or mechanical work, and which are absorbed in the processes of metabolism."

In the face of the great triumphs which physiological science celebrated by the introduction of chemical and physical methods, the majority of investigators became accustomed to the view, to which they were led, too, by the brilliant exposition of it by Du Bois-Reymond, that physiology, imagined as complete, is nothing else than biophysics and biochemistry, and that it has no just pretension to rank as a true science, except so far as it is an application of chemistry and physics, dynamics and mathematics.

From the extreme of a "shallow vitalism," as Du Bois-Reymond called it, physiologists mostly went to the opposite extreme of a desolate mechanism, and believed in the explanation of life as a purely chemo-physical process.

The first consequence was that physiologists in the regular line of the profession, with few exceptions, cultivated, by preference, only such fields as were adapted to chemo-physical methods of research, and left others, such as the physiology of development and generation, altogether untilled. But anatomists, zoologists, and botanists only insisted upon them so much the more. They penetrated deeper into the vital phenomena of the cell, of protoplasm, and of the nucleus. They discovered the wonderfully complicated process of the division of the nucleus, the spindle with its ray figures, and the centrosomes, the chromosomes, and their longitudinal segmentation, and finally they solved the old controversy which had once divided physiologists into the two camps of the animalculists and the ovists, for now the secret process of fertilization was happily settled in all its phases by simple microscopical observation. The penetration of a spermatozoon into an egg cell, the coalescence of the egg nucleus and the sperm nucleus were successfully and directly observed. They deepened the comprehension of the entire process by the discovery that egg and sperm cells must be prepared, in some sort, for the fructification, by the reduction or expulsion of half the matter of their nucleus, and finally, supported by these and other facts, they ventured to lay the foundation for the problem of heredity by the hypothesis that in the matter of the nucleus the vehicles of inherited characters are found.

So by the side of the chemo-physical school of physiology an anatomo-biological bias gained strength. This endeavored to deepen our inspection of life by microscopical research. But the anatomo-biological bias, the more it enforces itself (sich geltung verschafft) by its investigation of the organization of the substratum of life, will the more lead to the insight that the mechanical standpoint in biology is just as one-sided as the vitalistic. Truly one of the chief champions of the mechanistic doctrine—Du Bois-Reymond—has himself applied the critical probe to it and, in principle, has recognized its insufficiency. In his address upon the limits of the knowledge of nature he has set up two insoluble interrogation marks, which later, in his seven world riddles, he has increased to seven, and, really, I do not know why he should have restricted himself to so modest a number. Du Bois-Reymond characterizes the impossibility on the one hand of conceiving the essence of matter and force, and on the other hand of explaining even the lowest degree of consciousness mechanically, as a trite truth, and says that it is an old experience, which no discovery of natural science has in the least modified, that one equally fails whether one adopts the theory of atomism, of dynamism, or the opinion of plenum.

Du Bois-Reymond, it is true, has not himself drawn the conclusion which necessarily follows from this. But the conclusion which in the biology of the new century will victoriously break its way is that the mechanistic dogma that life, with all its complex phenomena, is nothing at all but a chemo-physical problem is as groundless as vitalism; groundless, at least, so long as one does not understand by physics and chemistry sciences of quite other nature than those which in their purport and their scope from the point of view of their historical development now present themselves. For, as I remarked upon another occasion, "If the problem of the chemist is to investigate the numberless combinations of different kinds of atoms to form molecules, he can, in strictness, not touch upon the problem of life, for this begins where his inquiry ends. Over the structure of the chemical molecule rises the structure of the living substance as a broader and higher kind of organization. Over the structure of the cell rises again the structure of plants and animals, which exhibit the yet more complicated, elaborate combinations of millions and milliards of cells coordinated and differentiated in the most extremely various ways."

What has chemical science, as it now is, to do with this entirely new world of organizations of matter, upon which the first manifestations of life depend? If the chemist wishes to set himself to the task of investigating these, the first thing he has to do is to become a biologist, and especially a morphologist. But then his methods and his aim must be very different from what they are, and far more comprehensive.

As for physics, it stands in precisely the same relation to biology that chemistry does. At present the physiological [physical?] school commonly argues with Du Bois-Reymond thus: In the living being, in the cell, no other forces are efficient than those which the atoms of the cell—carbon, hydrogen, oxygen, nitrogen, phosphorus, etc.—have displayed outside of the cell. "A particle of iron is and remains the very same sort of thing whether it flies through the solar system (Weltkreis) in the meteorite or dashes along upon the rim of the locomotive wheel or trickles in a blood cell through the temples of a bard. As little as in the mechanism of the human hand is there in the last case anything added to the properties of the particle or anything subtracted from them. Those properties are eternal. They are inalienable, untransferable." "But if the atoms have developed no new forces, everything of the physico-chemical kind will happen in the cell precisely as it would in a test tube."

That is the way the argument runs for the standpoint of "everything in the world is chemistry and physics." But our reply is that the word "atom" is merely a fiction useful for science in its present condition; that we know nothing of the sum of the properties and forces in an "atom in itself," and still less how from the properties and forces of different kinds of atoms we are to pass to the properties and forces of their compounds. That from the properties of carbon, combined with those of oxygen, hydrogen, nitrogen, etc., in certain proportions, albumen must result, is a fact as inconceivable in its essence as that from different albuminous bodies with special organization will come a living cell.

We therefore prefer, in the question which is occupying us, to leave out both the concept of an atom and also the extraordinarily difficult concept of a force of which so much misuse is made, and to confine ourselves to that by which alone a force can be known; that is to say, to its effects. But in reference to these I think and may assert the same thing as in reference to the organization of matter.

Just as by the joining together of atoms to make molecules, of the molecules to make the higher material units of the living cells, of living cells to make plants and animals, ever new, more numerous, and higher forms of organizations are created, so it is with the effects which proceed from them. With every one of the endless stages and forms of organization new modes of action are produced; and when the investigator comes to plants and animals he has to do with an entirely new world of uncommonly manifold effects, which do not occur in lifeless nature and which can not occur there, since the requisite organization is wanting. I will instance only the preservation of the species by growth and reproduction, metabolism, the different kinds of irritability, phototaxis, chemotaxis, geotropism, etc., consciousness, faculties of sense and thought, and, finally, all the different effects which single parts of cells exert upon each other, cell upon cell, organ upon organ, animals and plants upon one another.

Is it the business of the physicist to concern himself with effects of every kind which proceed from all the possible bodies in the world?

Certainly not. As the chemist concerns himself only with the simplest organization of matter, the chemical, but not with biological combinations, so the physicist, as a man of the science as it has historically grown to be, concerns himself only with a certain class of effects, which may be called the elementary ones—a class of effects, in itself considered, extraordinarily large, yet, in comparison with all the modes of action in the world, very small. Should the physicist not choose to impose this limitation upon himself, he would be obliged to unite in one person the labor of the physiologist and psychologist, the sociologist and historian, and whatever other study there may be.

Finally, let it be remarked that the current opinion that the investigation of life is nothing but a chemo-physical problem, and that everything in the world is physics and chemistry, is commonly connected with a gross overvaluation of chemo-physical science. It seems to be forgotten that this science, like everything human, is but a work of detail (ein Stückwerk), and at every point jostles against limits of natural knowledge which, for the time being, seem to be insuperable, and that chemistry and physics in this regard have no advantage over biology.

Nägeli well said, in 1877, in his address before the Munich congress upon the "Limits of the knowledge of the natural sciences," that

"Nature in her simpler inorganic phenomena presented the same difficulties for research as in the question of the occurrence of sensation and consciousness from material causes."

The simpler is by no means always the best known, and, indeed, the ordinary course of science is that from the study of the more complex we come to be acquainted with the simpler. In chemistry, analysis, for the most part, precedes synthesis. We have learned what a wonderful sort of element carbon is by having found analytically that it is the base of the carbohydrates, fats, albumens, and now develops in them properties which certainly nobody would have suspected in advance of the carbon in a piece of anthracite. What part the albuminous bodies play in the vital process we know, not by the chemical study of albumen, which can teach us nothing at all about it, but by the study of vegetable and animal cells. Thus science is built not merely from below upward, but quite as much, or even more, from above downward; there penetrating from the simple to the more compound, here from the compound to the simpler.

We have referred above to this syllogism: "If the atoms develop no other forces in the cell than what they have outside of it, then everything of a chemo-physical kind that happens in the cell takes place as it would in a test tube." In the same way and with equal justice we can contrapose this syllogism and so get something like the following: Man feels, remembers, and is conscious; he thinks and builds a world of thought. Since, now, man consists of cells, cells of molecules of albumen, and these, again, of atoms; since every higher stage of organization is naturally developed from the stage next below it, and since the conservation of energy allows no room for Thought to be introduced at any step of the process, it follows that the cell, the molecule, and the atom must feel, remember, be conscious, and think, each after its kind.

Indeed, just such views have already been put forth; and according to them, upon the most important questions, not only of the doctrine of cells but of chemistry and physics, the psychologist would have to be consulted for information.

But by such general reasonings, whether of the progressive or the regressive variety, which leave the solid earth of natural science to float, as it were, in the air, the man of science can reach no useful result. He ought to avoid them both.

The physicist and chemist refuse to recognize atoms that feel, have memory, or think, because they perceive no sign of such properties and their methods can not detect them. With the same justice the biologist must enter a protest against his science being regarded from the restricted standpoint of the chemist and physicist, since its problems and methods for the most part are quite of another sort (ganz anders geartete), and are at any rate much more comprehensive and are not near to being exhausted by physics and chemistry.

The man of science, in order to make his researches successful, must limit them to a small part of the immeasurable world problem, quite in contrast with the philosopher. Is it, then, any part of his task to set forth a general conception of the world (die Welt begreiflich erscheinen zu lassen) according to a formula? Is not the best notion for him to entertain that the world is capable of being investigated, but that for us, children of the present, the empire of the uninvestigated and of the obscure is a thousandfold greater than the empire of the investigated, of that which has already entered into our science and into human recognition?

The man of science, guided by such considerations, will be conscious that the explanation of the world as a mechanism of jostling atoms rests upon nothing but a fiction, which may be useful for exhibiting many relations, but yet does not correspond to the truth. So that world, deprived of properties, supposed by Laplace, who saw in the world process nothing but effects of atoms whirling past one another, together with a single great sum in arithmetic to be done by knowing the world rule, will seem to the man of science to be, in comparison with the real world, which speaks to him with its infinite properties through all his senses, as a nugatory shadow picture, comparable with those shades in the under world that, like fog, eluded the arm of Ulysses when he tried to seize them.

The scientific man who listens to reason will assent to the propositions in which Carl Ernst von Baer briefly, pertinently, and beautifully described the essence of science: "Science," said he, "is, in its source, eternal; in its operation, not limited by time and space; in its scope, immeasureable; in its problem, endless; in its goal, unattainable."

This last is particularly true of biology, the science of life. Its problem is of the most difficult. Its field extends in all directions, having the closest relations to all sorts of other sciences. In one direction, supported by chemistry and physics, it becomes biochemistry and biophysics. In a contrary direction it forms a connection with the psychical sciences, which relate to mere human nature, with psychology and sociology, with ethics and religion. By it the material and spiritual worlds are placed in connection. And so biology, in the newly dawning century, if its cultivators, free from dogmatic fetters of every kind, shall continue to convert the empire of the uninvestigated into the empire of human knowledge, will be summoned to cooperate, in an eminent way, in the inward civilization of the human race, elevating it to a higher stage, not only of intellectual insight, but also of social and moral conduct. It will so help to bring on the time when the wonderful progress which the nineteenth century has brought in the chemo-physical field by the expert mastery over the forces of nature shall first bring to coming generations its full blessing.

THE RESTORATION OF EXTINCT ANIMALS.

By Frederic A. Lucas,

Acting Curator, Section of Vertebrate Fossils, U. S. National Museum.

Many have been the attempts to recall the life of the past and set before us the living semblance of the animals that long ago walked on the face of the earth; and, while some of these reconstructions, such as those that disport themselves through the columns of the Sunday papers, have been literally creatures of the imagination, others, like those prepared under the direction of Professor Osborn, have been the result of long and careful studies of scientific men. The attitude of the public toward such restorations is varied; a few there be who accept them with implicit faith in their fidelity to nature, while others have as little confidence in the most careful reconstructions as in those made to order for the sensational newspaper or to fit the description of some weird story in a popular magazine. Between these extremes there is a golden mean. While we can not be certain that the best-made models or drawings correctly represent the animals as they were, we may be sure that they rest on a solid foundation of fact and do give a fairly good idea of the creatures for which they were intended. At the worst, they are infinitely better and vastly more correct than many of the older pictures of then little-known animals based on imperfect specimens, poor sketches, or highly colored descriptions of those who had actually seen the animals they were supposed to represent. They are even better and more true to nature than many figures drawn from stuffed specimens to be found in text-books, or even scientific works of the earlier part of the nineteenth century and, for aught the writer knows, Richardson's figure of the pocket gopher with his pockets turned inside out may still be doing duty.

It is but natural that we should desire to know how these strange and mighty animals, upon which man never gazed, looked in life, and this desire is ample justification for their restoration; and as material has accumulated and our knowledge of extinct animals has increased, it has become more and more possible to depict them with some degree of accuracy.

The oft-asked question, How long ago did these animals live? is one difficult to answer, the more that the discrepancy between the various estimates that have been made as to the age of the earth or of various portions of its crust are so great that they seem little more than mere guesses. The shortest estimate, that by Professor Newcomb, is ten million years; the longest, six billion. But, following the more conservative figures, we may say that the Dinosaurs (terrible lizards) lived from fifteen million to six million years ago, while since the beginning of the Eocene, when the mammals began to gain the ascendency, somewhere between three million and four million five hundred thousand years have elapsed.

Cuvier was probably the first to make a restoration of any extinct animal that was more than a mere guess, as he was the first to place such a restoration on the firm basis of scientific fact and deduction. These restorations of Cuvier's, figured on plate 147 of the celebrated "Ossemens Fossiles," were of several species of hoofed quadrupeds whose remains were found in the quarries of Montmartre and to which Cuvier had applied the names of Anoplotherium (weaponless beast)[1] and Palæotherium (ancient beast). Since their publication they have been, with occasional slight modifications, copied far and wide, and to-day even no well-considered text-book of palæontology is quite complete without them, although, curiously enough, while the figures are duly ascribed to Cuvier, no one seems to think it worth while to give the exact reference to the time and place of their publication.[2]

The deductions made by Cuvier from the bones of the Anoplotherium may serve as a good example of the manner in which the external appearance of an animal may be inferred from its internal structure. From the length of the tail and appearance of the bones of the feet he supposed the animal to have been more or less aquatic in habit; and, judging from its habit of swimming and diving, he went on to reason that "Anoplotherium would have the hair smooth like that of the otter; perhaps its skin was even half naked. It is not likely that it had long ears, which would be inconvenient in its aquatic life." But,

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[1] Literally, the weaponless beast, having neither claws, horns, nor large canines; and the ancient beast. Scientific men are often taken to task because so many animals have no common, or popular, names, the public forgetting that such can only be applied to animals that are well or commonly known. The scientific name of an animal is simply a tag or label attached to it by which it may be known, not merely where English is spoken, but the world over, and that they are no more difficult to understand or pronounce than so-called popular names is shown by the fact that many of them, such as elephant, boa constrictor, rhinoceros, etc., have been adopted as common names. Scientific names, it may be said, usually contain a reference to some character possessed by the animal to which they are applied.

[2] This reference is as follows: Recherches sur les Ossemens Fossiles où l'on retablit les caractères de plusieurs animaux dont les revolutions du globe ont détruit les espèces. Par Georges Cuvier. Atlas, Tome Premier, Planche 147. The reproduction herewith given is from the fourth edition, published in 1836.

comments Mr. Hutchinson, was it really aquatic? And this but hints at the uncertainty attending the work of restoration, for some peculiarities of structure may point more than one way or be subject to more than one interpretation.

Thus the short-limbed, heavy-bodied carnivore Oxyæna from our western country was at first considered to have had habits like those of an otter, while on a later review it has been thought to have been as arboreal in its mode of life as a raccoon. And while, as a general rule, aquatic animals or those of sluggish movements have solid bones, yet the extinct toothed diver Hesperornis has hollow leg bones and so does the huge Dinosaur Triceratops.

Cuvier's restorations were founded on his famous law of correlation, or the harmony to be found between various portions of the skeleton, between these and their investing muscles, and between the entire animal and its mode of life. For example, the retractile claws of a cat would not be found associated with the teeth of a ruminant, but with teeth fitted for devouring flesh and, conversely, teeth adapted for cropping grass and chewing the cud would be found in company with hoofs, while beasts that chew the cud and have cloven feet are the only ones that have horns on the frontal bones, so that a horned carnivore would be out of the question.

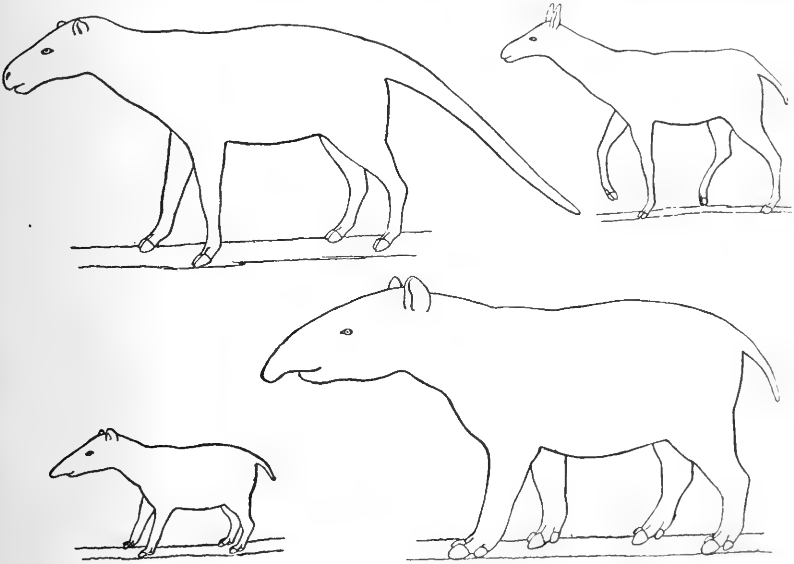


FIG. 1.—Cuvier's Restorations of Mammals from the Paris Basin. Reduced about one-half.

Anoplotherium commune.
Palæotherium minus.

Anoplotherium gracile.
Palæotherium magnum.

These great generalizations are, in the main, true, but Cuvier was dealing mostly with animals of a limited region, the Paris basin, and with types not strikingly different in structure from those that live to-day. Had he come upon some of the forms which have subsequently come to light he might well have been puzzled, for since the time of Cuvier animals have been discovered in which claws like those of a carnivore are combined with teeth fitted for a vegetable diet. Such a one is the animal called Agriochœrus (plant eater), from the Miocene of the West, and so strikingly at variance are the parts of the skeleton that, having been found at different times, the foreclaws were supposed to be those of a carnivorous mammal and described under the name of *Mesonyx* (middle claw), the hind foot dubbed *Artionyx* (straight claw), under the supposition that the beast was related to the sloths, while the skull with its herbivorous teeth bore the name of *Agriochœrus*. Not until the discovery of a fairly complete specimen in which the various parts were associated was this snarl of names disentangled. Still the occurrence of such forms are not precisely the exceptions that prove the rule, but expressions of the fact that the more recent animals are the more highly specialized or adapted for special modes of life, be they devourers of flesh or feeders upon herbs. So as we go back in the past we find the lines now sharply drawn between groups of animals fading out, forms appearing unlike any now living, and animals becoming more generalized, as it is termed, more like one another in internal structure, less fitted for some particular mode of life or kind of food, although some of these strange forms survived until a comparatively late date. Consequently it is more difficult to recognize the entire form and relations of the early animals from their scattered bones than it is those of the later arrivals upon the earth, and thus it has happened that some of the attempts at reconstructing the earlier and stranger forms have, in the light of more complete knowledge, been found to be very far from the truth.

In the Dinosaurs (terrible lizards), those great and ancient reptiles that have been the basis of many and careful restorations, we have a group of animals with which Cuvier was practically unacquainted and which in many ways differ from any other animals with which we are familiar. How different they are may be inferred from the fact that no less an authority than Owen mistook the bones of the hip for those of the shoulder of one of these creatures and so described and figured them. And this is not to be held to his discredit, for at the time almost nothing was known of the Dinosaurs, and while there is a popular belief that it is quite possible to reconstruct an entire animal from one tooth or a single bone this is, unluckily, very far from the truth. True, much may often be done with a bone or a tooth, but this is in cases where these fragments are unmistakably like those of creatures which we do know and with whose more or less complete structure we are well acquainted.

Probably the earliest restorations to be given to the general public (those of Cuvier having been published in a scientific work of limited circulation) were those by Sir Henry Delabeche, shown on the frontispiece to the second series of Buckland's Curiosities of Natural History, depicting a number of extinct animals, including Ichthyosaurs (fish lizard) and Plesiosaurs (a reptile). This was the first attempt at restoring these marine reptiles and it is to be noted that they are drawn with round, pointed tails. A little later Owen, noticing that in every skeleton of Ichthyosaur the terminal portion of the backbone was bent at an angle to the rest of the vertebral column, inferred that the tail was high and compressed, somewhat like that of a newt, and that the bend was caused by the sagging over of the tail as decomposition set in. So the next lot of restorations, including those made by Waterhouse Hawkins for the Crystal Palace, showed these creatures with flattened tails.

Years passed on and the famous deposits at Holzmaden, Wurtemberg, yielded up some beautifully preserved examples of Ichthyosaurs, which definitely settled the question of the shape of the tail, for: pictured on the rock by the hand of Nature was a deep, forked, vertical tail, not unlike that of some sharks in appearance, but with this striking structural difference that while in the tail of sharks the backbone is continued along the upper edge of the tail, in the fish-lizards the bone runs along the lower edge; the bend in the vertebral column was not a break at all, but a perfectly natural flexure. More than this, the specimens showed the presence, hitherto unsuspected, of a high back fin of whose existence there is no more trace in the skeleton than there is in modern whales of the presence of a similar fin. Behind the well-defined fin was a series of markings apparently indicating an irregular crest like that borne by the European Triton during the breeding season, and thus was Ichthyosaurus depicted in the next series of restorations. But if the first pictures had shown too little, these, on the other hand, showed too much, for subsequent study made it evident that the irregular markings following the back fin were accidental and formed no part of the reptile, and so the fourth and last stage of the Ichthyosaur represents an animal clearly built for speed, with a powerful, vertical tail, four paddles and a high back fin. The Ichthyosaur's companion in the Liassic Sea, the Plesiosaur, has also passed through various stages of reconstruction, first appearing with a long neck thrown into graceful, swan-like curves, the long-accepted version; next that of Dames, with a comparatively inflexible neck, while somewhere between the two lies the truth. For it may be taken for granted that any creature with a long, slender neck is capable of bending this about in search of food, even though it may not be possible for him to throw it into a series of graceful sigmoid curves. When, in 1852, the New Crystal Palace was erected at Sydenham, England, it was resolved to have as one of the features of the surrounding grounds a group of restorations of extinct animals, and Mr.

B. Waterhouse Hawkins was placed in charge of the undertaking. As it was not intended that these figures should be approached closely they were built on a gigantic scale and located on a small wooded islet where they formed conspicuous features in the landscape. The size of the figures may be inferred from the materials used in constructing the Iguanodon, for these comprised four iron columns 9 feet long and 7 inches in diameter, 600 bricks, 1,550 tiles, 38 barrels of cement, and 90 barrels of broken stone, besides bar and hoop iron. But little was known of the Dinosaurs at that time, and this dearth of information, coupled with the fact that Mr. Hawkins was not deeply versed in comparative anatomy, resulted in the making of some rather singular animals. Megalosaurus (great lizard) and Iguanodon (Iguana-toothed) were represented as huge lizards, walking on four massive limbs, the former with a head between that of a crocodile and a monitor, the latter with one very obviously patterned after that of an iguana, and with the spike-like claw of the thumb placed on the tip of the nose. Still we should not be too severe on Mr. Hawkins for, as we have seen, Owen himself mistook the hip bones for the shoulder blade, and the very boldness of the attempt and the scale on which it was carried out deserve commendation. Granting even that these restorations were very largely erroneous, they were the first to be brought conspicuously before the public and served a good purpose in creating popular interest in the study of paleontology.

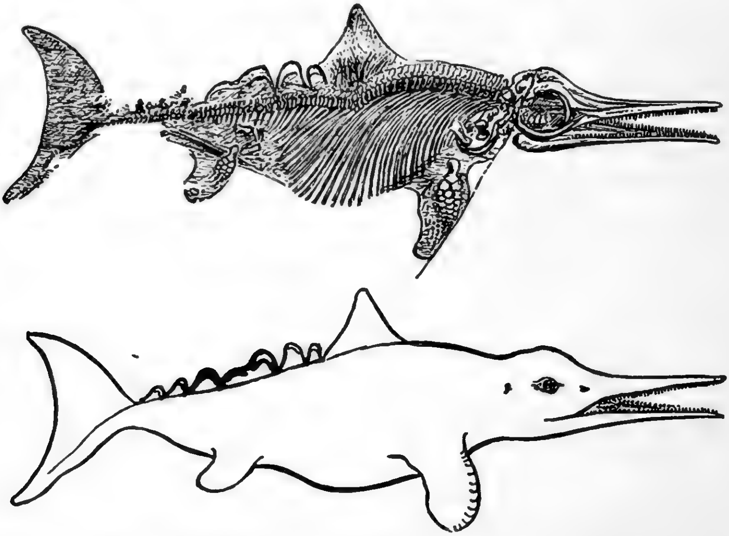
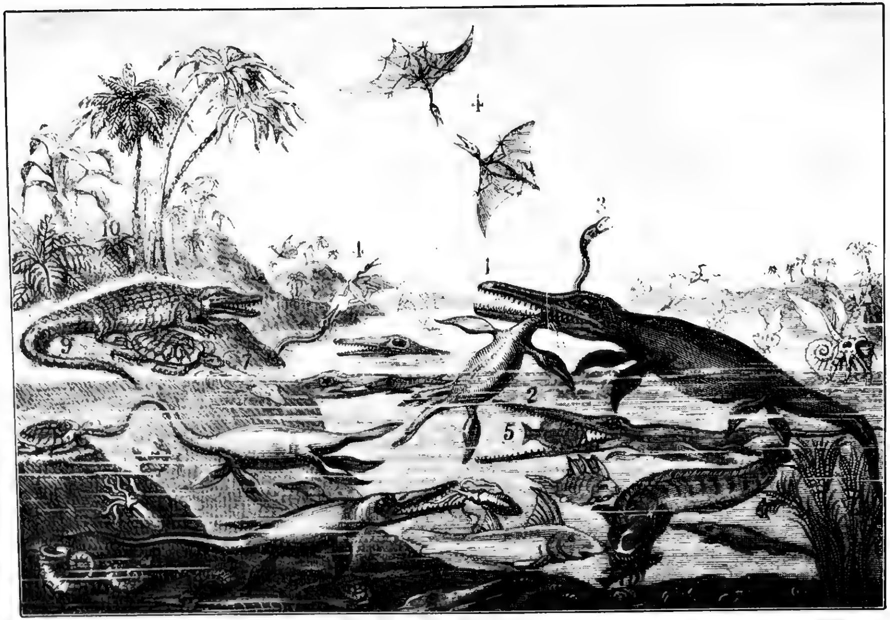


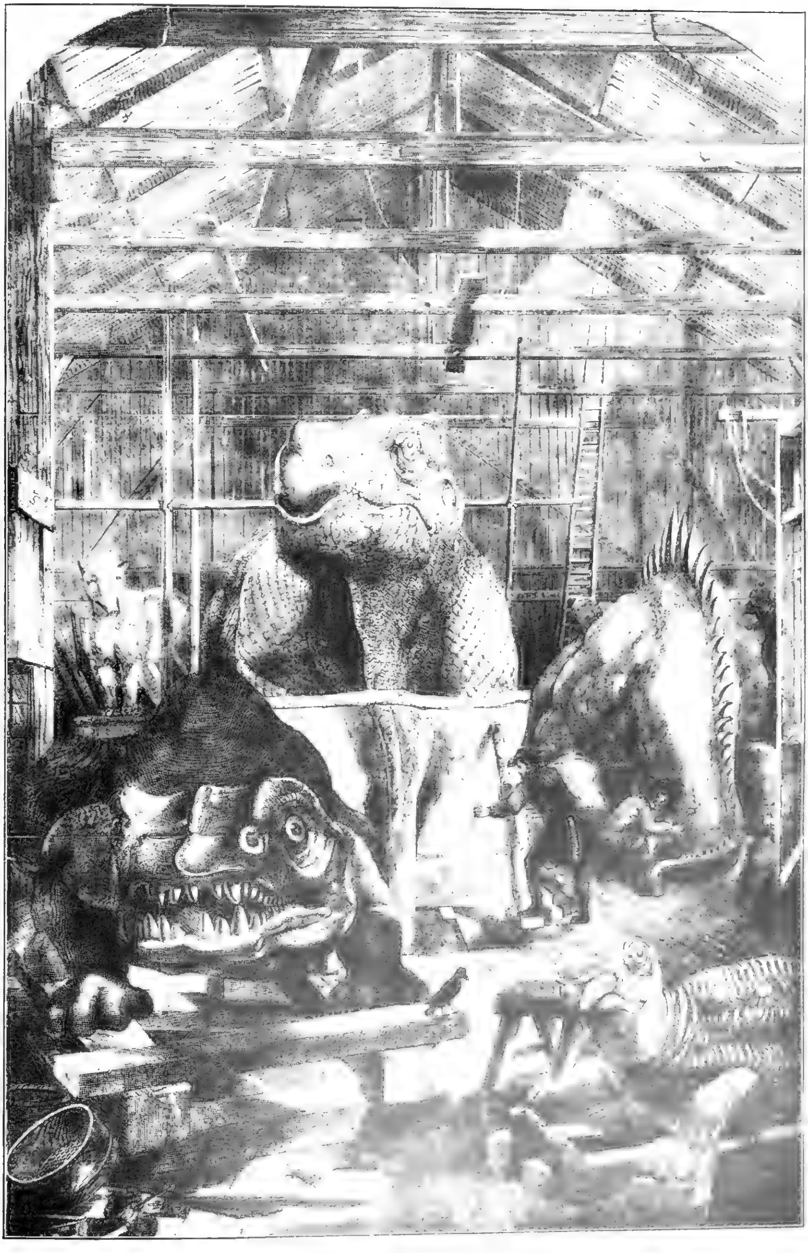
FIG. 2.—Specimen of Ichthyosaur found at Holzmaden, showing the impression of the dorsal and caudal fins and restoration based on this specimen. After Fraas.

The most recent restorations are those prepared by Mr. Charles R. Knight under the direction of Prof. Henry F. Osborn for the American Museum of Natural History, New York, and a few made by Mr.



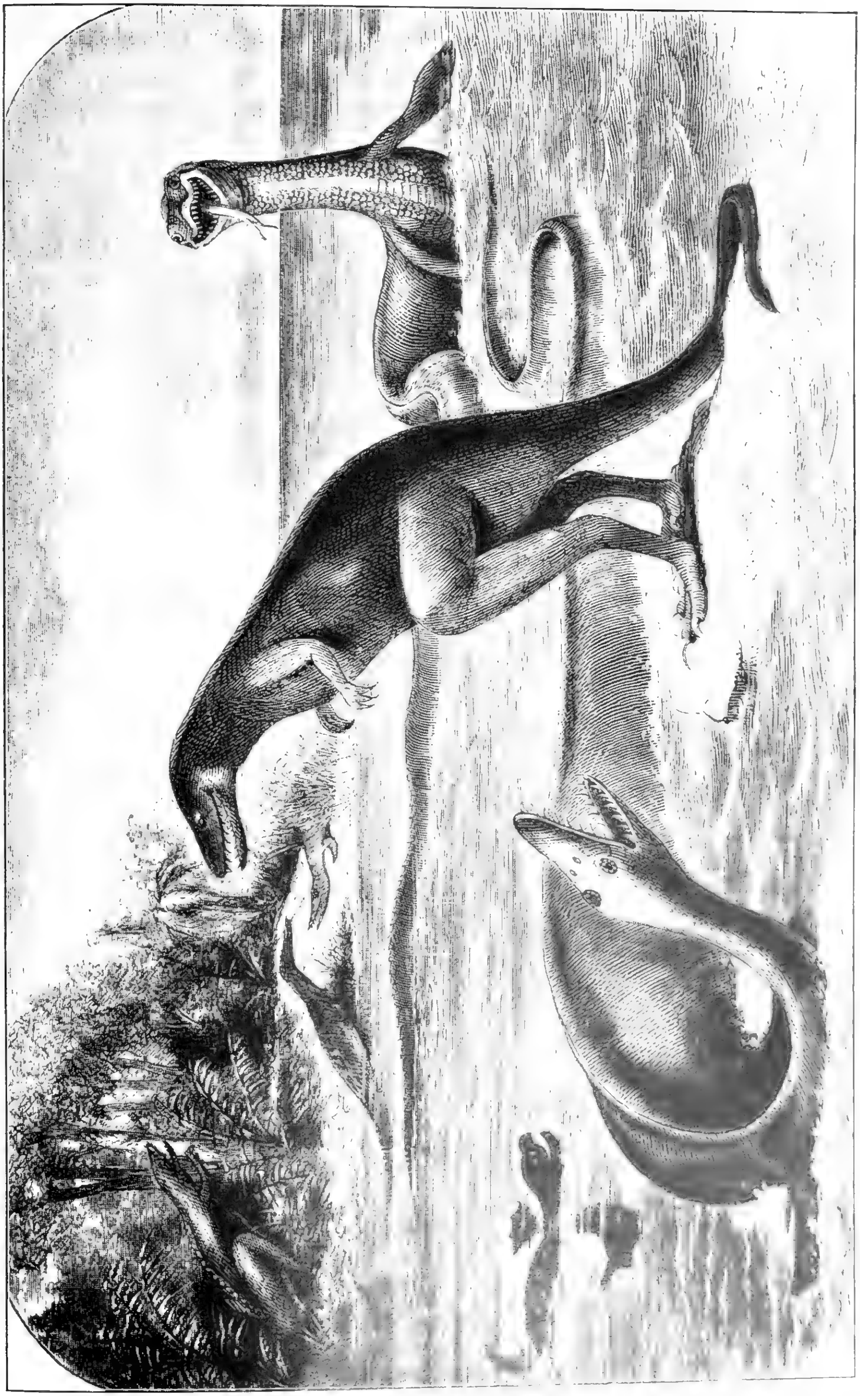
SIR HENRY DELABECHE'S RESTORATIONS OF EXTINCT ANIMALS.

Reproduced from Buckland's Curiosities of Natural History, second series.



WATERHOUSE HAWKINS'S WORKROOM AT THE CRYSTAL PALACE.

Reduced from a picture in The Illustrated London News.



PROFESSOR COPE'S RESTORATIONS OF CRETACEOUS REPTILES.

Reproduced from The American Naturalist

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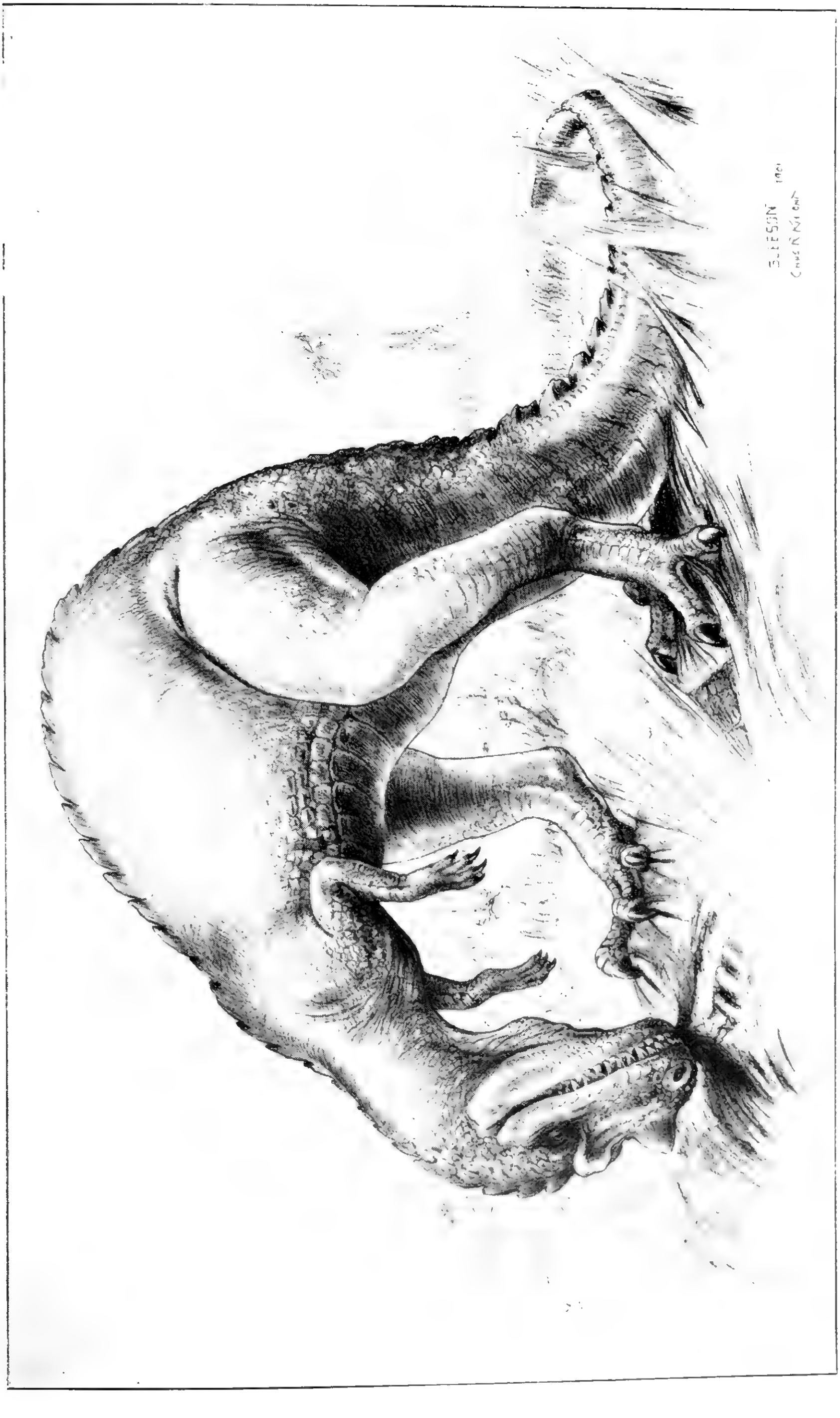
TYLOSAURUS.

Drawn by J. M. Gleeson. By permission of the S. S. McClure Company.



CERATOSAURUS.

Drawn by J. M. Gleeson. By permission of the S. S. McClure Company.

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Knight and Mr. Gleeson for illustrative purposes for the S. S. McClure Company, two of which are, by the courtesy of the publishers, included in this article. As an artist Mr. Knight has devoted himself to the representation of animals, and these have all been prepared with the greatest care and after a careful consideration of the skeletons of the various animals represented and of their form and habits as deduced from the skeleton. Hence they may be looked upon as giving as accurate an idea as we can now form of the appearance of these extinct animals. They well illustrate the importance of combining artistic ability with anatomical knowledge and an acquaintance with the external appearance of animals, as may be seen by comparing the plates of Tylosaurus (ram lizard) and Ceratosaurus (nose-horned lizard), drawn by Mr. Gleeson, with the plate of Cretaceous reptiles drawn under the direction of Professor Cope. The marine reptile on the right of this plate is a Mosasaur, the animal standing on the sand bank in the foreground is Lælaps, a Dinosaur related to if not identical with Ceratosaurus. Professor Cope, who supervised the drawing of this plate, had anatomical knowledge, but the artist who drew the figures neither understood the animals he was endeavoring to represent nor had a good knowledge of living animals.

Before passing to the restoration of the exterior of animals it may be well to say something of the manner in which the skeleton of an extinct animal may be restored and the meaning of its various parts interpreted; for the adjustment of the muscles is dependent on the structure of the skeleton, and putting on the muscles means blocking out the form, details of external appearance being supplied by the skin and its accessories of hair, scales, or horns, things which may or may not have a direct relation to the underlying bones. For example, there is nothing in the skeleton of the Indian rhinoceros to indicate that its skin is put on in great folds, nor, so far as we can see, is there any reason why they should be present in this species and lacking in all his relations with which we are acquainted. Neither is there any internal reason why the trunks of the African and Indian elephants should be so different from one another as they are.

Let us suppose that we are dealing with one of the great reptiles known as Triceratops (three-horn face),[1] whose remains are among the treasures of the National Museum, for the reconstruction of this big beast may well illustrate not only the methods of the paleontologist, but also the troubles by which he is beset. Moreover this is not a purely imaginary case, but one that is very real, for the skeleton of this animal, which was reproduced in papier-maché for the Buffalo Exposition, was restored in exactly the manner indicated. And then, in order to give as vivid an idea of the animal as possible, a small model of the creature

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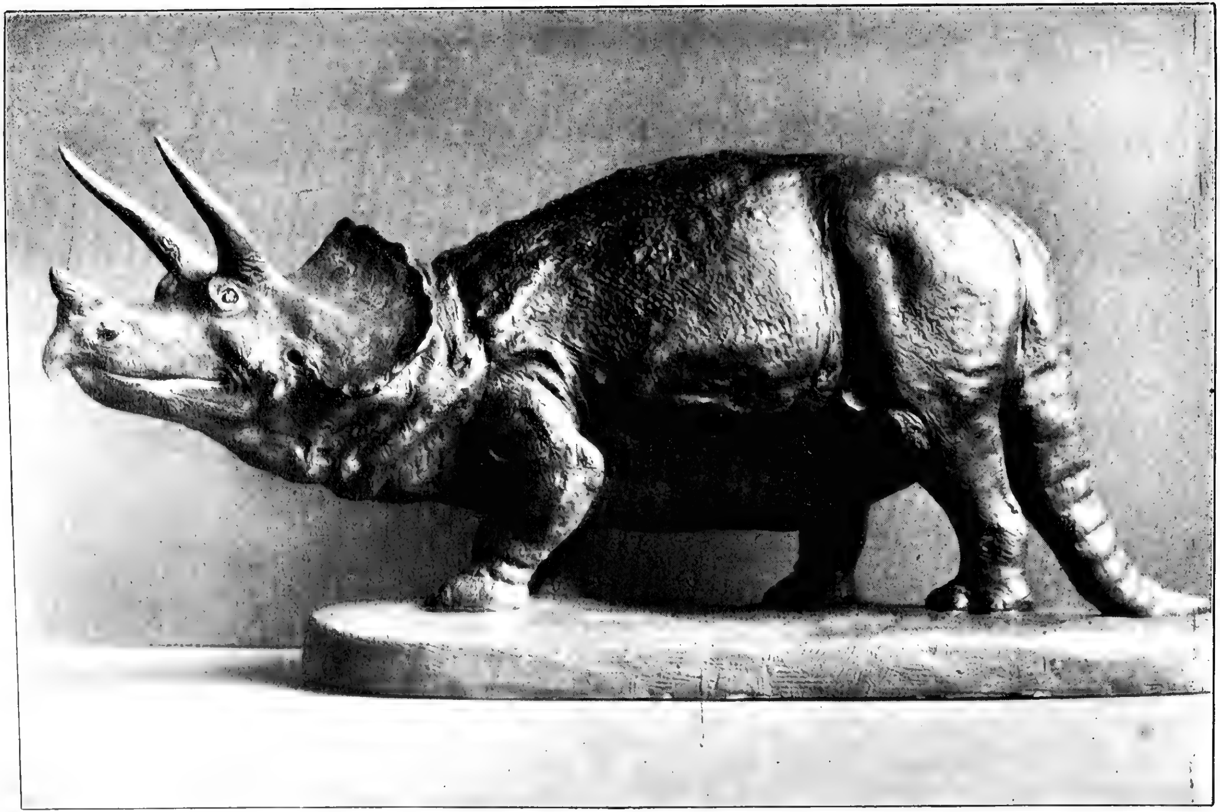
[1] In allusion to the presence of the two large horns above the eyes and the third smaller horn on the nose.

was made by Mr. Knight, as well as a painting showing Triceratops as nearly as he might be supposed to look amid his natural surroundings, perhaps six million or more years ago.

We have a goodly number of bones, though by no means an entire skeleton, and yet we wish to complete the skeleton and incidentally to form some idea of the creature's habits. Now, we can interpret the past only by a knowledge of the present, and it is by carefully studying the skeletons of the animals of to-day that we can learn to read the meaning of the symbols of bone left by the animals of a million yesterdays. Thus we find that certain characters distinguish the bone of a mammal from that of a bird, a reptile, or a fish, and these in turn from one another, and this constitutes the A, B, C of comparative anatomy. And, in a like manner, the bones of the various divisions of these main groups have to a greater or less extent their own distinguishing characteristics, so that by first comparing the bones of extinct animals with those of creatures that are now living we are enabled to recognize their nearest existing relative, and then by comparing them with one another we learn the relations they bore in the ancient world. But it must be borne in mind that some of the early beasts were so very different from those of to-day that until pretty much their entire structure was known there was nothing with which to compare odd bones. Had but a single incomplete specimen of Triceratops come to light we should be very much in the dark concerning him, and although remains of some thirty individuals have been discovered, these have been so imperfect that we are very far from having all the information we need. A great part of the head, with its formidable looking horns, is present, and although the nose is gone we know from other specimens that it, too, was armed with a knob or horn, and that the skull ended in a beak something like that of a snapping turtle, though formed by a separate and extra bone. Similarly the end of the lower jaw is lacking, but we may be pretty certain that it ended in a beak to match that of the skull. The large leg bones of our specimen are mostly represented, for these being among the more solid parts of the skeleton are more frequently preserved than any others, and though some are from one side and some from another this matters not. If the hind legs were disproportionately long it would indicate that our animal often or habitually walked erect, but as there is only difference enough between the fore and hind limbs to enable Triceratops to browse comfortably from the ground, we would naturally place him on all fours, even were the skull not so large as to make the creature too top-heavy for any other mode of locomotion. Were the limbs very small in comparison with the other bones, it would obviously mean that their owner passed his life in the water, for a skeleton is the solution of a problem in mechanics—given a certain amount of weight to support, and there must be limbs of a given size if this weight is to be carried on dry land. If the animal is buoyed

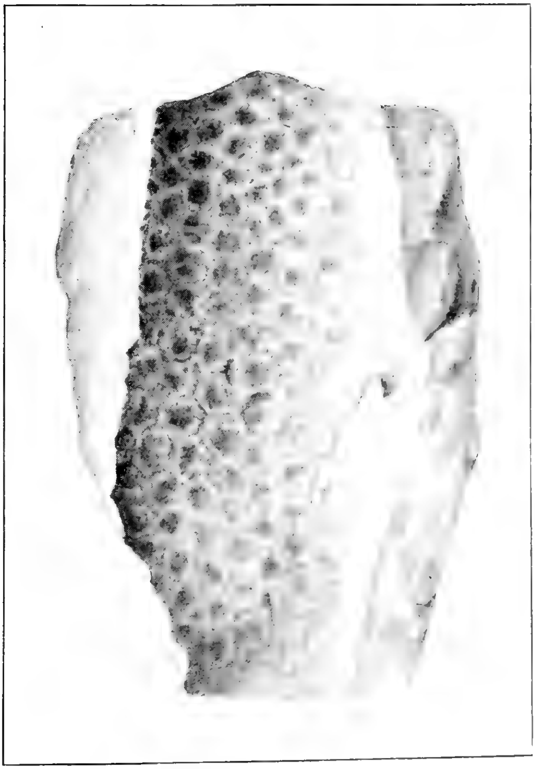
PLATE VI.



TRICERATOPS.

From a statuette by Chas. R. Knight.

Sandstone bearing the Imprint of Skin of Thespesius (very much reduced).



Drawing of Portion of the above Specimen (Natural Size), showing the Structure of the Skin.

up by water the legs are not needed for locomotion, and may be very small.

Something, too, may be gathered from the structure of the leg bones, for solid bones mean either a sluggish animal or a creature of more or less aquatic habits, while hollow bones emphatically declare a land animal, and an active one at that, and this in the case of the Dinosaurs hints at predatory habits, the ability to catch and eat their defenseless and more sluggish brethren. A claw, or better yet, a tooth, may confirm or refute this hint, for a blunt claw could not be used in tearing prey limb from limb, nor would a double-edged tooth, made for rending flesh, serve for champing grass.

But few bones of the feet, and especially the fore feet, are present, these smaller parts of the skeleton having been washed away before the ponderous frame was buried in the sand, and the best that can be done is to follow the law of probabilities and put three toes on the hind foot and five on the fore, two of these last devoid of claws. The single blunt round claw among our bones shows, like the teeth, that Triceratops was herbivorous; it also pointed a little downward, and this tells that in the living animal the sole of the foot was a thick, soft pad, somewhat as it is in the elephant and rhinoceros, and that the toes were not entirely free from one another. There are less than a dozen vertebræ, and still fewer ribs, besides half a barrelful of pieces, from which to reconstruct a backbone 20 feet long. That the ribs are part from one side and part from another matters no more than it did in the case of the leg bones, but the backbone presents a more difficult problem, since the pieces are not like so many checkers, all made after one pattern, but each has an individuality of its own. The total number of vertebræ must be guessed at (perhaps it would sound better to say estimated, but it really means the same), and knowing that some sections are from the front part of the vertebral column and some from the back, fill in the gaps as best we may. The ribs offer a little aid in this task, giving certain details of the vertebræ, while those in turn tell something about the adjoining parts of the ribs. We finish our Triceratops with a tail of moderate length, as indicated by the rapid taper of the few vertebræ available, and from these we gather, too, that in life the tail was round and not flattened, and that it neither served for swimming nor for a balancing pole.

So much for the manner in which, piece by piece, the framework of an animal is put together, and what the various parts may tell of the life and habits of some creature that long ago passed out of existence.

The basis of all reconstruction is, of course, the skeleton, and since, as said above, we can read the past only by the aid of the present, it is absolutely essential to have a knowledge of the anatomy of creatures living to-day in order to properly interpret the bones of those that lived a million years ago; not only that, it is equally essential to have more than a casual acquaintance with their external appearance, for, while there is nothing in the bones to tell how an animal is or was covered, there are certain general rules for telling what the probabilities are.

A bird, for example, would certainly be clothed in feathers, for these are the exclusive property of birds; no other creature possesses feathers, no bird is without them, although they may be so modified that at first sight their identity might be called in question. Reptiles and mammals may go quite naked or cover themselves with a defensive armor of bony plates or horny scales, but under the blaze of the tropical sun or in the chill waters of arctic seas birds wear feathers and feathers only. Going a little further, we might be pretty sure that the feathers of a waterfowl would be thick and close; those of strictly terrestrial birds, such as the ostrich and other flightless forms, lax and long. These as general propositions. Of course in special cases one might easily come to grief, as in dealing with birds like penguins, which are particularly adapted for an aquatic life and have the feathers highly modified. These birds depend upon their fat and not on their feathers for warmth, and these have become a sort of cross between scales and hairs. Hair and fur belong to mammals only, although these creatures show much variety in their outer covering. The thoroughly marine whales have discarded furs and adopted a smooth and slippery skin,[1] well adapted to movement through the water, relying for warmth on a thick undershirt of blubber. The earless seals, that pass much of their time on the ice, have just enough hair to keep them from absolute contact with it, warmth again being provided for by blubber. The fur seals, which for several months in the year dwell largely on land, have a coat of fur and hair, although warmth is mostly furnished, or rather kept in, by fat.

No reptile, therefore, would be covered with feathers; neither, judging from those we know to-day, would they be clad in fur or hair; but such coverings being barred out, there remain a great variety of plates and scales to choose from. Folds and frills, crests and dewlaps, like beauty, are but skin deep, and, being thus superficial, ordinarily leave no trace of their former presence, and in respect to them the reconstructor must trust to his imagination with the law of probabilities as a checkrein to his fancy. This law would tell us that such ornaments

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[1] The reader is warned that this is a mere figure of speech, for, of course, the process of adaptation to surroundings is passive, not active, although there is a most unfortunate tendency among writers on evolution, and particularly on mimicry, to speak of it as active. The writer believes that no animal in the first stages of mimicry consciously mimics or endeavors to resemble another animal or any part of its surroundings, but a habit at first accidental may in time become more or less conscious.

must not be so placed as to be in the way, and that while there would be a possibility—one might even say probability—of the great, short-headed, iguana-like Dinosaurs having dewlaps, that there would be no great likelihood of them possessing ruffs, such as that of the Australian Chlamydosaurus (mantled lizard), to flap about their ears; even Stegosaurus, with his bizarre array of great plates and spines, kept them on his back, out of the way. Such festal ornamentation would, however, more likely be found in small, active creatures, the larger beasts contenting themselves with plates and folds.

Spines and plates usually leave some trace of their existence, for they consist of a superstructure of skin or horn built on a foundation of bone, and, while even horn decomposes too quickly to "petrify," the bone will become fossilized and changed into enduring stone. But, while this affords a pretty sure guide to the general shape of the investing horn, it does not give all the details, and there may have been ridges and furrows and sculpturing that we know not of.

Knowing, then, what the probabilities are, we have some guide to the character of the covering that should be placed on an animal, and if we may not be sure as to what should be done we may be pretty certain what should not.

For example, to depict a Dinosaur with smooth, rubbery hide, walking about on dry land, would be to violate the probabilities, for only such exclusively aquatic creatures as the whales among mammals and the salamanders among batrachians are clothed in smooth, shiny skin. There might, however, be reason to suspect that a creature largely aquatic in its habits did occasionally venture on land; as, for instance, when vertebræ that seem illy adapted for carrying the weight of a land animal are found in company with huge limb bones and massive feet, we may feel reasonably certain that their owner passed at least a portion of his time on terra firma.

So much for the probabilities as to the covering of animals known to us only by their fossil remains, but it is often possible to go beyond this and to state certainly how they were clad; for while the chances are small that any trace of the covering of an extinct animal, other than bony plates, will be preserved, nature does now and then seem to have relented, and occasionally some animal settled to rest where it was so quickly and quietly covered with fine mud that the impression of small scales, feathers, or even smooth skin was preserved. Curiously enough, there seems to be no record of the imprint of hair having been found. Then, too, it is to be remembered that while the chances were very much against such preservation, in the thousands or millions of times creatures died the millionth chance might come uppermost.

The imprints of ichthyosaurs have already been mentioned, and these are probably due to the slow carbonization of animal matter, leaving a dark silhouette of the animal printed on the smooth rock.

Impressions of feathers were known long before the discovery of Archæopteryx; a few have been found in the Green River and Florissant shales of Wyoming, and a Hesperonis in the collection of the State University of Kansas shows traces of the existence of long, soft feathers on the tibia, and very clear imprints of the scales and reticulated skin that covered the tarsus. From the chalk of Kansas, too, came the example of Tylosaur, showing that the back of this animal was decorated with the crest shown in Mr. Knight's restoration, one not unlike that of the modern iguana. From the Laramie sandstone of Montana Mr. Hatcher and Mr. Butler have obtained the impressions of portions of the skin of the great Dinosaur Thespesius, which show that the covering of this animal consisted largely, if not entirely, of small, irregularly hexagonal horny scutes, slightly thickened in the center. The quarries of lithographic stone at Solenhofen have yielded a few specimens of flying reptiles—pterodactyles—which not only verify the correctness of the inference that these creatures possessed membranous wings like the bats, but they show the exact shape—and it was sometimes very curious—of this membrane.

And each and all of these wonderfully preserved specimens serve both to check and guide the restorer in his task of clothing the animal as it was in life.

And all this help is needed, for it is an easy matter to make a wide-sweeping deduction, apparently resting on a good basis of fact, and yet erroneous. Remains of the mammoth and woolly rhinoceros found in Siberia and northern Europe were thought to indicate that at the period when these animals lived the climate was mild—a very natural inference, since the elephants and rhinoceroses we now know are all inhabitants of tropical climes. But the discovery of more or less complete specimens makes it evident that the climate was not particularly mild; the animals were simply adapted to it. Instead of being naked, like their modern relatives, they were dressed for the climate in a woolly covering. We think of the tiger as prowling through the jungles of India, but he ranges so far north that in some localities this beast preys upon reindeer, which are among the most northern of large mammals, and there the tiger is clad in fairly thick fur.

When we come to coloring a reconstructed animal we have absolutely no guide, unless we assume that the larger a creature the more soberly will it be colored. The great land animals of to-day, the elephant and rhinoceros, to say nothing of the aquatic hippopotamus, are very dully colored, and while this somber coloration is to-day a protection, rendering these animals less easily seen by man than they otherwise would be, yet at the time this color was developing man was not, nor enemies sufficiently formidable to menace the race of elephantine creatures, for where mere size furnishes sufficient protection one would hardly expect to find protective coloration as well, unless indeed a creature preyed upon others, when it might be advantageous to enable a predatory animal to steal upon its prey.

Color often exists, or is supposed to, as a sexual character, to render the male of a species attractive to or readily recognizable by the female; but in the case of large animals mere size is quite enough to render it conspicuous, and possibly this may be one of the factors in the dull coloration of large animals.

So while a green and yellow Triceratops would undoubtedly have been a conspicuous feature in the Cretaceous landscape, from what we know of existing animals it seems but to curb our fancy and, so far as large dinosaurs are concerned, employ the colors of a Rembrandt rather than those of a sign painter.

Aids, or at least hints, to the coloration of extinct animals are to be found in the coloration of the young of various living species, for as the changes undergone by the embryo are in a measure an epitome of the changes undergone by a species during its evolution, so the brief color phases or markings of the young are considered to represent the ordinary coloring of distant ancestors. Young thrushes are spotted, young ostriches and grebes are irregularly striped, young lions are spotted, and in restoring the early horse, or Hyracothere, Professor Osborn had the animal represented as faintly striped, for the reason that zebras, the wild horses of to-day, are striped, and because the ass, which is a primitive type of horse, is also striped over the shoulders, these being hints that the earlier horse-like forms were also striped. Applying the principles just laid down to the model and drawing of Triceratops, it was decided to show him in a fairly thick and smooth skin, for from what we actually know of the covering of large dinosaurs, as shown by Thespesius, the horny scutes of which it is composed are so small that they would not show at all in a small model or picture. A few dermal plates have been found in the Triceratops beds, but these are not definitely known to have belonged to that animal; in fact, there is good reason to believe that they are from another species;[1] and so the presence of a row of horny scutes down the center of the back was merely hinted at, while the knee and elbow were given callosities such as might properly have belonged there.

The sides of the neck were depicted with folds or ridges of skin suggested by those found in the iguana, horned toad, and other lizards, but for reasons given these were not shown as rising into long, decorative points, since such would be more likely to occur in small reptiles than in large. And because of his size and the blackish or dull green color of large reptiles, the color of Triceratops was made a dull greenish gray, lightened beneath into a yellowish hue.

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[1] Among the pitfalls by which the path of the restorer is beset is the fact that the bones of different species of animals are often found so associated that they seem to have belonged together, and in the present instance Thespesius is found with Triceratops.

The restoration of the common or American mastodon (*Mastodon americanus*), drawn by Mr. J. M. Gleeson, to accompany this article, may be taken as another example of the methods followed in reconstructing extinct animals.

The mastodon is an elephant, and his general appearance is indicated, but there are certain details some of which are purely deductive and some of which have fortunately been proved for us. The skeleton shows that, taking the skeleton as a whole, the mastodon and African elephant represent two extremes of elephantine structures, the latter being the highest or longest legged, the former being for its bulk the lowest, most massive species, known, although low is a comparative term, for the animal attained a height of 10 feet. Yet when the skull and teeth are considered, these two animals have decided points of resemblance. The skull of the African elephant is flatter than that of the Indian species; the skull of the mastodon is even more depressed, and, as this feature would have shown plainly in life, it should be borne in mind in making any restorations. Many mastodon tusks have been found, and thus we know that they were slightly heavier, more abruptly tapering than in the mammoth or Indian elephant, and that, while there was great variety in the curve, in the typical examples from eastern North America they described nearly a half circle. In supplying the mastodon with a trunk it is to be borne in mind that there is a striking difference between the trunks of the Asiatic and African elephants, that of the former wrinkling up when bent, as though it were equally elastic throughout, while that of the latter bends, as it were, in sections, suggesting the joints of a telescope. As the skull and teeth of the mastodon are simpler in structure than those of the Indian elephant, and in these particulars more like the corresponding parts of the African elephant, it is a fair inference that the trunk was similar and that it also lacked the finger-like process of the Indian species. The northern mammoth was clad in hair and wool, and, as the mastodon ranged well to the north, it is fair to suppose that the more northern individuals were more or less completely clad in hair. And this supposition is substantiated by the discovery noted by Titian Peale of long, coarse, wooly hair, in one of the swamps of Ulster County, N. Y. Thus the restoration of the mastodon represents a proportionately lower, more heavily built elephant than those now living, with recurved tusks and jointed trunk, and clad in fairly long hair.

Finally, it may be gathered from what has been said that, while the restoration of extinct animals is subject to some uncertainties, and mistakes of interpretation are liable to occur, these efforts to reproduce the living forms of past ages are not mere guesswork, but rest upon a solid foundation of scientific facts and careful deductions.

THE MASTODON.

Drawn by J. M. Gleeson.

LIFE IN THE OCEAN.[1]

By Karl Brandt.

On account of the favorable situation of the University of Kiel on the seacoast, a part of the corps of instructors of the university has, for a long time, but especially since the creation in 1870 of the Kiel commission for the scientific study of the German seas, directed its labors principally toward the study of the phenomena of life in the ocean.

The field is vast; it not only brings rich harvests to zoologists, botanists, and oceanographers, but also supplies valuable data to the chemist, the physicist, the physiologist, and hygienist. Our university, which originally had rather the character of a provincial institution of Schleswig-Holstein, has been insensibly metamorphosed into a special German university for the study of the things of the sea, while a part of our instructors at the same time teach in the naval academy. This specialization has been made known abroad by the fact that the first great German expedition for marine exploration, called the Plankton expedition, was carried out by members of our university. To the work of the commission for the scientific study of the German seas is due also the particular character of the researches carried on at Kiel during the second half of the century now closing, that is, since biological study of the ocean has been somewhat extended. The commission was assigned the task especially of investigating marine phenomena from the point of view of the exploitation of their animal resources; its labors mark the first step in a course having for its principal aim the discovery of the general laws which govern the phenomena of marine life, and of which the knowledge is necessary for the best success of the fisheries.

Questions of general biology have thus been brought to the front, and methods have been invented for penetrating the secrets of the deep for the profit of mankind. We are still far from our goal. For to reach it, observations, however numerous, on the behavior of the organisms that live in the sea, or their mutual relations, and on the

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[1] Translated from Revue Scientifique, 4th series, tome 12, October 21, 1899.

influence of external conditions, will not suffice; it is requisite besides to extend the conquests of science to the things of the sea, and to apply to the special beings that live therein the fundamental principles and approved methods of animal and vegetable physiology which have been deduced from the terrestrial world. We may sum up all these researches as the science of the totality of exchanges of matter in the ocean, and I will indicate here the most important of the investigations and the facts which must form the basis for the solution of the problem. I shall dwell especially on those points which present a general interest.

Matter in nature follows a cycle which may be briefly described as follows: The constituents of the air, the water, and the earth are transformed by vegetation into living substances; animals directly or indirectly absorbed the organic substances produced by plants, and finally animals and plants after their death are decomposed by the influence of certain bacteria into inorganic substances which, taken up again by plants, are transformed anew into organic matter, and so on.

It is the corpuscles of chlorophyll which enable plants in the presence of light to form organic substances from carbonic acid, water, and certain salts. It is on the other hand from the vegetable kingdom that all animals have to derive all the organic matter that is to form their bodies and support their life. It follows that in any large territory the quantity of organisms is regulated by the condition that the total mass of consuming animals has to remain inferior to the mass of producing plants. Unless this condition is fulfilled, a part of the animals must suffer hunger or even perish. For the same reason among terrestrial animals the mass of carnivores must be inferior to that of the herbivores.

But the plants can not perform the important function that devolves upon them—the formation of organic substances—unless they find the inorganic matter which is indispensable to them, and which presents itself under the form of combinations of at least eleven or twelve known chemical elements. If but a single one of these nutritive substances is wanting the plant will not grow. In case of insufficiency the plant just manages to exist; while if there is superabundance it grows rank. The growth of plants depends upon the quantity of nutritive matter they get, and there is an indispensable minimum for each species. The discovery of this fundamental law is due to Liebig, the founder of agricultural chemistry.

Generally speaking, the production of vegetable substances depends upon the quantity of nitrogenous inorganic compounds in the soil. We know that manures rich in nitrogen extraordinarily augment the vegetable production, although this can not surpass a certain maximum characteristic of each kind of plant, beyond which all increase of nitrogenous matter acts as a poison.

Inorganic nitrogenous compounds appear in three forms in nature—those of ammonia, nitrates, and nitrites. Since no plant can grow unless it finds inorganic nitrogenous compounds in its neighborhood, and since the life of animals depends on that of plants, it follows that all the life on the globe depends absolutely upon the existence of these nitrogenous compounds. It is, therefore, of the first importance to follow closely the cycle of transformations of nitrogen in nature.

We know only three sources of the three kinds of nitrogenous compounds which interest us. In the first place, all living beings contain nitrogenous substances, notably albumen, and these are in part eliminated during life as residuary products (urine, etc.), and for the rest are decomposed by putrefaction after death. The albuminoid substances are then transformed into ammonia, which in its turn furnishes nitrites and nitrates, so that the nitrogen is brought back to a form in which it can be used by plants in a new production of albumen. All the processes of putrefaction by which animal carcasses and vegetable remains are transformed into carbonic acid, subterranean nitrogenized waters, and other inorganic substances, are due exclusively to certain definite bacteria. If these are not present or do not meet with the conditions of life which they require, putrefaction is adjourned and with it the utilization of the nitrogenous matter of dead bodies by living ones.

Nor is the decomposition of albuminoids the only process caused by bacteria; they are equally necessary for the conversion of ammonia into nitrous acid, and ultimately into nitric acid, and for the reverse changes. A sort of bacterium called a nitrifying bacterium, or nitrobacterium, existing, it would seem, all over the globe, produces the oxidation necessary to transform ammonia first into nitrous and finally into nitric acid, provided there is enough oxygen at hand. The reverse process of reduction is due to another kind of bacterium, called a denitrifying bacterium, which transforms nitric acid into nitrous acid, and this again into ammonia, and finally sets nitrogen free. The final product of this reduction consists of free nitrogen, which, mingling with the air, is lost from the cycle of transformation. With one exception, nitrogen can not be utilized by plants to form albumen unless it is in a state of combination. Thus, though the greater part of the organic nitrogen returns to living organisms, a certain portion of it is lost by the action of the denitrifying bacteria. The quantity of living organisms would, therefore, be gradually diminished were there no other source of combined nitrogen to make up for the loss.

This compensation is furnished by the free nitrogen of the atmosphere, which, under certain conditions, can enter into combination and become available for plants. Combinations of this kind are brought about in two ways—by the action of lightning, that is, of electrical discharges, and by the symbiosis, or mutual parasitism, of certain plants with certain sorts of bacteria. It is leguminous plants alone, and of leguminous plants only those upon whose nodes certain bacteria live, that can fix the atmospheric nitrogen and use it to make albumen. In the absence of the specific bacteria the leguminous plants lose this property and behave like other plants, as can be seen by cultivating them in sterilized soil. In respect to compensation for losses of nitrogen, the intimate union between leguminous plants and certain bacteria is probably of far more importance than the fixation of nitrogen by atmospheric electricity.

As far as we know, the cycle whose essential steps have just been sketched is performed in the sea as on the land. In water, as on land, plants alone furnish the food; but, since they can not produce organic matter without light, they grow only in the upper strata of the ocean, down to a depth of some hundreds of meters. The marine plants are, moreover, equally subject to the law of the minimum. The analysis of the medium in which they live—that is to say, of the water with the solid and gaseous substances that it holds in solution—will permit the formation of conclusions analogous to those that soil analysis suggests for terrestrial plants. Moreover, as well as we can judge from recent observations, nitrifying and denitrifying bacteria play important parts both in fresh water and in the ocean.

The three nitrogen compounds of which we have spoken, together with all their salts, are particularly soluble, and, consequently, rains carry off a part of the compounds of this kind. The water thus charged with ammonia and nitric acid flows off by the ditches and brooks to the ponds, lakes, and water courses, and ultimately reaches the sea. The land is, in that way, continually being robbed of a certain quantity of nitrogen compounds, to the profit of the sea. The loss thus sustained by the soil is made up by the formation of new quantities of nitrogen compounds, due in small part to the action of storms, but, probably, chiefly by the intervention of bacteria living in the nodes of leguminous plants.

One naturally expects to find in the sea an animal and vegetable life far more intense than on land, for the reason that the sea, in the course of time, must have been extraordinarily enriched with nitrogenous substances. Indeed, it seems that the incessant bringing of such substances ought, after some hundred thousands or millions of years, to have poisoned the sea and rendered life there quite impossible. Yet, in point of fact, we neither find that life in the ocean has been cut off, nor do we meet there any very extraordinary wealth of living organisms or of nitrogen compounds. On the contrary, the few observations made enable us to declare that sea water does not contain so much combined nitrogen as earth does. This apparent contradiction may, in the present imperfect state of our knowledge, be supposed to be explicable by the action of denitrifying bacteria. From this point of view, the differentiation of the different kinds of bacteria which take part in the processes of putrefaction in the sea, the study of their modes of action, conditions of existence, and propagation will be of great interest.

Besides a general knowledge of the cycle of transformations of matter, we need the knowledge of the composition and transformation of the plants and animals that we have to study and of the action upon them of their environment in order to comprehend the phenomena of nature and to solve the practical questions to which they give rise. It is needful, also, to at least determine the importance of the commonest species.

Practical agriculture has gained great benefit from investigations of this sort and from results obtained in regard to the relations which exist between the many factors of the question.

Advantages have also been derived from many conquests of science for the utilization of ponds, and it may be hoped that the same principles applied to marine matters will lead to a more complete utilization of the products of the sea. The object of cultivating the soil is to obtain with the smallest possible expense and least work the greatest product. Efforts tend to augment the fecundity of the soil by such a study of the causes of that fecundity as permits the elimination of harmful influences. In the same way we ought to endeavor to get from the sea the greatest possible quantity of useful products. For that purpose, the first thing to be done is to make an exact inventory of the real product of the ocean, or only of a particular, part of the sea, compared with what is furnished by cultivated soil. This exact knowledge of the production gives the surest point of departure not only for a rational exploitation of sea fisheries, but also for a study of the causes of production and of the transformations of matter in the bosom of the ocean.

There are exact statistics of agriculture. Thus we know that in Germany an acre of meadow yields on the average 1.4 short tons of hay. In order to be able to compare this crop with the product of the same area planted with cereals, or with that of a pond of the same size, we must know the chemical composition of the plants in question, so as to be able to compare the different plants, either directly according to their amount of albumen, of fatty matters, etc., or indirectly according to their nutritive value, determined by special experiments. To ascertain exactly the annual production of flesh per unit of surface is less easy. The most satisfactory method is still that of deducing it from the number of young cattle that can be raised annually upon a suitable area. According to the data collected by Viebahn an acre of cultivated land in Prussia yields 75 pounds of beef per annum. For water, as for land, we can, as Hensen has shown, try two different ways of ascertaining the yield. We can weigh the fish taken from a pond, and thus determine the quantity of useful flesh produced per acre per year, or we can find the quantity of organic matter produced in the form of plants in a given body of water in a year. The values found for the yield in flesh and for the production of nutritive substances must have a certain ratio which may be ascertained by chemical bacteriological and physical study of the body of water in question from the point of view of its capacity of yield. The product of fish in flesh can be directly determined only in ponds that can be emptied and from which all the fish they contain can be taken. Susta gives extended instructions for doing this in his interesting work on feeding carp. The worst ponds give nearly 11 pounds of carp per year to the acre; but large ponds generally give three or four times as much, while the yield of the small ones is six times as much. Village ponds into which flows manure liquor from farms give a yield running up to twenty times the first number.

The observations made upon the exploitation of ponds furnish some information concerning the causes of the variations of production. Those ponds into which flow either the water from manured land or the drainage of villages are always better stocked and give a better yield. The introduction of nitrogen compounds has thus here, as in the case of the soil, the effect of augmenting the yield very remarkably. It has also been found that the yield can be much increased by giving the fish food rich in nitrogen (grains of lupine, etc.). This food is not in all cases directly assimilated. It seems, on the contrary, that it is first taken by larvæ of gnats, worms, insects, etc., which afterwards become the prey of the fish, or else that the food, by the intervention of certain bacteria undergo a decomposition having the effect of rendering them assimilable by the plants of the pond, these plants being then eaten by small animals which, mixed with microscopic plants, serve in their turn as food for the carp. In any case, experience shows that the conditions of production in a small body of water are by no means unfavorably affected by the presence of manure, but that on the contrary they may be greatly improved in this way.

The simple and sure process of directly ascertaining the production of fish is, of course, no longer applicable when we come to large lakes or to the sea, because it is then no longer possible to take out all the fish. We have, then, to fall back on the best statistics. According to the catch of the fishermen, Hensen has estimated the annual yield of the Bay of Hela (meaning, presumably, the Putziger Wiek, in the Gulf of Dantzig) at 28.2 pounds per acre (31.6 kilos de poisson pour 1 hectare de surface en eau). I have calculated in another way that in the "Haff," at Stettin (l'anse de Stettin), the catch of fish amounts to 90 pounds per acre per year (100 kilos par hectare et par an). On the other hand, Heincke sets down the annual value of the products drawn from the German Ocean as from 100,000,000 to 150,000,000 marks, and, according to British statistics, 11 pounds (5 kilos) of fish are worth 1 mark (23.82 cents, or 2⅙ cents per pound). Consequently the total catch of the German Ocean would be from 1,100,000,000 to 1,650,000,000 pounds, or from 8 to 12 pounds per acre, worth 17½ to 26¼ cents.[1]

This production is very low, as compared with that of fish ponds. In the latter the catch may give some idea of the production, but at sea the fishermen only keep such fish as are profitable and can generally only take a part of the fish. The real production of the German Ocean is, therefore, quite unknown. It is true that in a fish pond or field the greater part of the parasites can be destroyed, while in the sea we can not prevent the concurrence of creatures which, though they are not worth catching and transporting (if they are of any value at all), nevertheless draw their food from the general store. Still, I think it highly improbable that the actual catch in the German Ocean represents more than a small fraction of the real useful production. We can only say that if the fishermen take all that could be taken the proportionate production of the German Ocean is not a third of that of the worst class of fish ponds. Besides, the best statistics of fisheries give but rough approximations, having rather a relative than an absolute significance, so that it is quite likely that the catch is much greater than the statistics show. In the case of the "Hafen" of Stettin, careful verification showed me that the actual catch was between two and one-half and three times as great as the statistics showed. It may be that the statistics of the German Ocean are nearer the truth, yet it is certain that they do not include all the products of the sea. For example, the enormous masses of seaweed that are thrown up upon the shores by storms and are then utilized by farmers are not taken into account.

It would be desirable that each year all the fish should be taken from the sea that it can naturally produce, and it would be interesting to know how much this is, in order that we may take all that can be taken without inconvenience to future production.

Hensen has proposed to deduce the quantity of fish from the number of eggs deposited in the spawning season. For the majority of species of useful fish these eggs do not sink, but float, so that the motion of the water, whether by currents or by wind, assure their being pretty uniformly distributed. By making dippings with a fine net it is easy to ascertain the number of eggs and larvæ contained in the vertical column of liquid of a given base, and by operating in this way over an important body of water a great many times every day, so as to correct contingent errors and possible variations, one will certainly

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[1] 500,000,000 à 650,000,000 de kilos par hectare, ou 9 à 13.6 kilos, représentant une valeur de 1.8 à 2.7 marks.

succeed in gaining a tolerably exact idea of the distribution of eggs, and consequently in acquiring practically important knowledge concerning the situation and extent of the places preferred by the fish for laying their spawn. These experiments will also furnish valuable data in regard to the quantities of eggs laid by each kind of fish. It is even possible to pursue quantitative experiments, showing the loss at each period of the development of the larvæ. Knowing the quantity of eggs which each species of fish can give, we can finally deduce from the figures furnished by these soundings the quantity of fish really existing in the waters under study at the spawning season. The comparison of the figure so obtained with the statistics of the fisheries will give the ratio between the fish taken and the annual increase.

This method is the only one hitherto proposed which permits us to get an exact idea of the situation. It has thus far only been applied to the fisheries of the Kieler Bucht (la rade de Kiel) in the Baltic and of the German Ocean. These applications have shown that the method is correct in principle and reliable in its application. New observations, however, on fish eggs and their development are yet needed to give the process an absolutely certain basis. These observations are, moreover, indispensable in order to elucidate a number of important, practical, and scientific questions. A quantity of isolated experiments, hitherto of no particular consequence in default of any general principles by which they might be interpreted, become to-day indispensable bases of further researches.

The animals which inhabit the sea are developed in proportion to the quantity of their food. Now, since all this food comes directly or indirectly from plants, it follows that we can just as well estimate the real production of animal life in the water by means of the annual yield of vegetation as we can estimate the product of a farm by the quantity of grass and fodder that it affords. The vegetable produce of the sea belongs to two forms markedly distinct. On the one hand there are the multicellular shore plants of some size, such as fucus or wrack, sea lettuce and green seaweed generally (algues vertes), dulse and other florid seaweed (algues rouges), and kelp (herbe marine). On the other hand there are unicellular organisms so small that with a very few exceptions, they are not distinguishable by the naked eye. The large plants are all collected into a narrow band along the shore, while the microscopic plants are not only found on the border and at the bottom of shallow arms of the sea, but constitute an essential part of the plankton which floats freely in the water. Ideas of the relative importance of the two classes as food are widely divergent owing to the insufficiency of observations hitherto made upon the subject. But if we consider the ocean as a whole, it can hardly be doubted that the quantity and consequently the direct importance of fucoids, florids, and algæ generally is very feeble as contrasted with that of the imperceptible plants which multiply in the free water. The shore alone is bordered by a belt, sometimes quite a meager one, of large plants which, beyond this belt, hardly grow except in shoal water, for the deeper we go the more scanty we find this vegetation.

Suppose the land had no vegetation beyond a similar zone along the coasts. Is it not evident that it could feed but a very small number of large animals? But to render the parallel perfect it would be necessary to suppose the desert surface of the continent more than twice as large, for the ocean covers more than two-thirds of the surface of the globe. The comparison would be rendered still more unfavorable by the fact that at least on German coasts the living marine plants in question are eaten only by a relatively small number of small animals.

But it is not necessary to dwell upon the matter, for it is clear that the food of the animal world of the sea has to be assured under another form.

The tangles and the bottom of the shallows are covered with plants extraordinarily small, nearly comparable to the green algæ which clothe the branches of trees, or to mosses. These small plants of rapid growth are much more quickly devoured than the great bundles of fucus (varech) or of laminaria (herbe marine) hard as stone. To make the parallel good it would be necessary to imagine the whole body of the continents to be covered with a thick carpet of verdure, for nothing like sandy deserts or mountain solitudes where but a few animals can maintain a precarious existence are to be found in the ocean. There is vegetation everywhere, and Schütt has well said that the sailor who fancies he has pure water under him really sails everywhere, even in the blue ocean, in the midst of a rich vegetation. At the same time, this vegetation feeds such an extraordinary number of animals that it always appears to be scanty, because the vegetable substances newly produced are devoured as fast as they are produced.

From the point of view of food for animals there is the same difference between the two categories of marine plants as in our latitudes there is between trees and the soft plants of the fields. Like the trees, the fucus (varech) and the laminaria (les herbes marines) take a great development because they are little interfered with (gênés). They strike the eyes more, but in reality it is the meadow which provides food for the herds, meager as it looks. In respect, however, to the conditions under which they are found, the fields of the ocean differ from the fields of the land. The former grow plants of the size of the smallest grains of dust distributed through the upper strata of the sea, and prospering the better for being so regularly distributed. This regularity is assured by the incessant stirring of the ocean, and if any irregularity were to occur it would soon disappear, for if the vegetable organisms are relatively few at any one place they will thereby be enabled to utilize the light and the food so much the more to their advantage, so that their development will become more rapid; and besides, where there are fewer vegetable organisms animals will be less attracted, and consequently the destruction of them will be less.

Like the microscopic vegetable organisms the animalcules that live upon them are in general regularly distributed over the face of the waters. This is true especially in the open sea, for inshore the wind, the currents, and the possibility of using a different food often come in to modify the distribution of the greater animals. These modifications are still greater at the spawning season, because the fish then collect together. At this season certain kinds of fishing may become profitable which at other times has to be given up on account of the dispersal of its objects.

The regularity of the distribution of the little organisms in sea water led Hensen to the notion of applying to the determination of the vegetable production a process analogous to that used for producing eggs. The method of studying plankton quantitatively which Hensen invented and perfected for the purpose mentioned is of great importance for all biological investigations on the sea. The fundamental idea of this method is that it is proper to bring back to a single point of view all the observations on the influence of the conditions of the sea and on the mutual relations of marine organisms; on the transformations of matter and the chemical constitution of marine substances; on the quality and quantity of vegetable and animal organisms living in the water. In the first place it is necessary to collect, as far as possible, all the plants which are found under a definite area of the surface of the water. To do this, Hensen proposes the use of nets with very narrow meshes, by which a vertical column can be, so to speak, filtered, and make a statistical statement of the organisms so lifted. Unfortunately the finest nets now obtainable allow the passage of the microscopic vegetations which sometimes appear in important masses in certain regions. Hence it would be necessary to invent for those excessively minute organisms special methods of quantitative analysis. However, Hensen has obtained interesting results. Each drawing of the net represents the total organisms of the plankton down to a size of at least 0.048 mm. that at a given time and place are contained in a vertical column of known dimensions. By reason of the regularity of distribution of the organisms the results can, moreover, be extended to considerable areas—hundreds of square kilometers of open ocean—over which the conditions of life are uniform. Near the coast and within currents the conditions are different; so that it is proper there to take samples at lesser intervals. Furthermore, in order to gain a close acquaintance with the plankton of a body of water, it is necessary to repeat the experiments at the shortest intervals of time possible during at least a year.

It is not enough to measure the volume of organisms collected. It is necessary to estimate the number of individuals of each sort. Although this counting involves great expenditure of time, it is quite indispensable to the ascertainment of the production. It is necessary, in fact, to separate the producers from the consumers. It is proper, also, to take into account, at least for the principal species, the rapidity of increase, the duration of the different stages of development under the various conditions of life, the mode of alimentation and the needs of the principal animals. The results of the drafts taken at the beginning of the year may be regarded as a principal sum of money, of which the interest is spent in the course of the year, the capital remaining at the end about what it was at the beginning. The comparison of the quantities of animals of each sort and size in the successive drafts, together with the knowledge acquired by direct observations of their alimentary needs, enable us to infer whether the consumption is really sufficient to absorb the annual vegetable production. This comparison requires a very large set of drafts, because the rate of augmentation of the different species depends upon the conditions of life, and consequently varies from one season to another. Finally, the chemical analysis of the principal plants is necessary if we wish to compare the productivity of the sea in organic matters with that of the land.

It has been questioned whether it is possible to acquire an exact notion of the production of a part of the sea by observations of the plankton alone. But the objections which have been made neglect the fact that under natural conditions a body of sea always produces as much as possible, and that in a small body, like the Kieler Bucht, for example, the production in the middle of the water, and even along the coasts out of the light—a production which is the same for the whole surface—depends essentially upon the nutritive matters that the plants find in solution in the water. But in consequence of the incessant stirring up and mixing of the water, there can be no sensible difference between the nutritive matters which are presented to the plants in the open sea and in inshore places. Consequently the attentive observation of the plankton taken up, as has been said, in a particular place during a whole year, furnishes a sufficiently accurate scale of comparison for an estimate of the capacity of production of the whole body considered, whether the production inshore is a little less or a little more than that of the open sea.

Thus far, the method of the quantitive examination of the plankton has been applied to the following marine bodies:

First. In shoal water:

(*a*) During several years: The Kieler Bucht (possibly the Kieler Hafen is meant).

(*b*) During all seasons of one year:

In the Arctic zone, the Fjord of Karajak, in Greenland, in latitude 70° N., by Vanhœffen.

In the Mediterranean, at the Straits of Messina, by Lohmann.

In the Tropics, the Roads of Ralum in New Pomerania (formerly New Brittania), in latitude 4° S., by Dahl.

(*c*) During the winter months (1888–89):

In the Bay of Naples, by Schutt.

Second. On the high seas, by a series of drafts during the course of voyages of exploration:

In the Baltic (from Memel to Gotland); in the northern part of the German Ocean, from Skagen to the Hebrides; in a great part of the Atlantic during the Plankton expedition (from the middle of July to the beginning of November, 1889); in the part of the sea between the Lofoden Islands and the north of Spitzbergen during the Prince of Monaco expedition, in July and August, 1898.

I shall here leave out of consideration the numerous results which these observations have furnished in zoology, zoogeography, and oceanography, and confine myself to two points. The first is that shallow seas are richer in plankton than deep seas are, and that among the latter the Saragasso Sea is particularly poor (in August). The explanation of this is to be sought in the law of the minimum. In soundings, the influence of the soil and of the land with its contributions is more sensible, and plants find in a less mass of water a relatively great quantity of inorganic substances which, in the depths of the ocean, are more scattered and are specially deficient in the upper layers, where alone vegetation is possible. The substances in the unlighted depths can not be directly used by plants. On the other hand, as the great currents of the ocean extend along the coasts they bring to the upper layers of the high seas new food for the plants, so that these layers may be relatively more productive than the Saragasso Sea, whose waters are still and in the middle of which the conditions of alimentation appear to be altogether unfavorable.

It would be important to ascertain by chemical investigations which of the substances susceptible of feeding vegetation exists in smallest amounts. It is probably combined nitrogen. The results mentioned above, as furnished by fish ponds, lead toward this conclusion. In the same line are the experiments of Apstein on the lakes of Holstein, experiments which I have verified, showing that lakes rich in plankton contain much nitric and nitrous acids, while lakes poor in plankton are also poor in nitric acid, the quantity of plankton and the percentage of nitrates being sensibly proportional.

The second point to which I wish call attention in the results of the quantitative study of plankton—and it is the more striking of the two—is that tropical seas and the temperate zones are relatively poor in plankton, while the Arctic Ocean is rich. On land it is just the reverse. Luxuriant vegetation and superabundance of animal life are characteristic of the Tropics and mightily contrast with the meager vegetation and sparse population of the polar solitudes; and one would expect beforehand to find the same contrast in marine life. Plants, for example, need light to produce organic matters. Now, tropical seas are better lighted than glacial seas. High temperatures, too, are favorable to the development of marine organisms. Finally, the extraordinary variety of forms in tropical seas seems to argue greater wealth. Without Hensen's methods we should not have suspected the remarkable fact mentioned.

First of all, we must make sure that the results of the Plankton Expedition are correct. This expedition only drew its samples during a part of the year, so that it might be that at other seasons the relative poverty of the tropical seas would be transformed into great wealth. In order to ascertain how much there was in this objection, observations were made on different coasts in very different latitudes during a whole year, while at the same time as many additional observations as possible were made in deep water. We thus find at our disposition numerous observations made in the three oceans at my solicitation, by the Messrs. Schott, of Hamburg; Captain Bruhn, of Bremerhaven, and Naval Surgeons Krämer, von Schwab, and Freymadl. All these observations lead to the same conclusions: The Arctic regions are very rich in summer, while the tropical regions are poor in plankton the whole year round. Conditions specially unfavorable to production appear in the Mediterranean, as in the Saragossa Sea. The single comparison of the curves of volume for the four coast stations where the results have been most accurate confirms this conclusion. If we take the ärithmetical means of the monthly values we find that in New Pomerania the mean volume of plankton for the year is double that at Messina, while for the Kieler Bucht it is ten times that at Messina.

How shall we explain this remarkable fact, this bizarre contrast between the production of living substances on land and in the sea? First of all, we must get it clearly in our minds that the development of plants, and consequently their production, depends not only on the illumination, but also and in quite as large measure on the quantities of nutritive substances that are brought to them. If one of these substances, say combined nitrogen, is present only in relatively small amount, the production will suffer from this want. Penury of nitrogen is suggested, not only by the considerations put forth above, but also in a striking way by the fact that, according to the drafts of plankton, the quantity of nutritive substance in minimum ought to depend very much upon living organisms. Even slight differences of temperature have great importance for the quantity of plankton collected, and these differences of temperature affect chiefly the vital activity of the organisms—for example, of the marine bacteria—while they are nearly without effect upon the solubilities of the inorganic matters which are adapted to becoming food for the vegetation. It thus seems that the cause of the richness of cold waters and of the poverty of warm waters should be sought in the difference of development of the bacteria of putrefaction in the largest sense of the term, and in the influence of these bacteria on the proportion of nitrogenous compounds in the water.

Among these bacteria, the nitrifying bacteria exercise their function in arable soil only at a temperature above about 5° C. (41° F.). In all probability there are in the sea other sorts, nitrifiers and denitrifiers, able to accommodate themselves to other temperatures. Still, in the present state of our knowledge, we may assume that bacteria cease to act at the freezing point, or a little below that point. But if denitrifying bacteria can not perform their function in cold waters, it follows, almost necessarily, that polar seas must be richer in nutritive substances than tropical seas. In a large part of the polar seas the temperature of the whole liquid mass from surface to bottom remains even in summer, near 0°. North of a line extending from eastern Greenland to Norway, through Iceland and the Faroe Islands, the temperature at the bottom is generally below 0° C. South of this line the temperature of the deep waters of the Atlantic is certainly not much higher, because the cold water of the polar seas flows into the deep regions toward the equator. But at 1,000 meters (547 fathoms) the temperature is already 4° to 5°, and for depths of less than 100 meters, as well as along the coasts, it is notably higher, so that the bacteria here find, precisely as in the productive layers of tropical seas throughout the whole year, conditions favorable to their life. In the temperate zones the destruction of nitrogenous compounds is too limited during the winter and it is only in summer that it becomes important. Finally, in the Mediterranean the conditions of life of bacteria are still more favorable than in the Tropics, because a bar across the Straits of Gibraltar prevents the cold water from entering. Hence, even at great depths (of about 4,000 meters), there is always a temperature of 12° to 16°, which explains the development of bacteria in the whole liquid column observed and the consequent striking quantitative poverty in plankton of the Mediterranean Sea.

If we can not dismiss absolutely the idea of a denitrification that can not be neglected in the ocean, it appears to me highly probable, according to the observations hitherto made, that this decomposition of the principal vegetable nutritive substances is preferentially accomplished in warm regions.

NATURE PICTURES.[1]

By A. Radclyffe Dugmore.[2]

While book-illustrating has changed continually since printing was first discovered, the greatest improvement has been made in pictures of birds and animals. It is largely to the camera that we owe this great improvement. The accompanying illustration of a stormy petrel is a somewhat grotesque but yet a good example of the earlier work of the ornithological artist. It is reproduced from The Natural History of Birds, by Count de Buffon, printed in England in 1793. Until quite recently only drawings were used for illustrations, and with subjects such as birds "the personal equation" played so prominent a part that one felt a certain sense of doubt as to the accuracy even of fairly good drawings.

For my own part I had never been satisfied with drawings of birds; and therefore, giving up the pencil, I followed in the footsteps of those who were experimenting with bird photography. All my earlier attempts were with mounted specimens, at first without any accessories. But the photographs seemed hard and unlifelike. Then I tried placing the mounted bird in natural surroundings, either out of doors or beneath a skylight. The pictures were fairly satisfactory, but still there was no disguising the fact that the bird was mounted. The eyes, and usually the legs, told the story. The pictures were unsympathetic; it was as though one had photographed the wax model of a friend. The likeness was there, but the life was lacking. And there was another objection; although to the casual observer the specimen may appear well mounted, how rarely is shown the characteristic pose so subtle and delicate in its infinite variety. But few taxidermists are naturalists, and without endless study of living birds how can anyone expect to know the attitudes assumed by the different species? The

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[1] Copyright, 1900, by Doubleday, Page & Co. Reprinted, by permission, from The Worlds Work, November, 1900.

[2] It is hardly necessary to tell anyone who looks at Mr. Dugmore's pictures reproduced here that they are all photographed from live birds. Many are wild birds taken in the woods with "snap shots," by hard work and good luck, as explained by the author.

human eye itself is scarcely quick enough to take note of these things, and it is to the camera that we must turn, and use it as eye, notebook, and pencil. It was the realization of this fact that led me finally to try the fascinating but difficult task of photographing the living bird.

To begin with, only nestlings were my models, and I was delighted with the results—no glass eyes nor dried-up legs to mar the picture, but expressions as varied as they were beautiful, and positions entirely different from those seen in mounted specimens. These successes led me, of course, to attempt photographing the adult bird, and I made many experiments with tame birds. It was necessary to have a place arranged so that there might be abundant light; and to avoid sameness in the arrangement of the lighting, the contrivance must be movable. I made a wooden plate form (supported on two light wooden horses) about 6 feet long, and covered it with mosquito netting stretched on a light framework. The background was of wood, to which could be attached paper or cloth of any desired shade. The camera could be moved backward or forward and secured with a tripod screw. Into this portable cage the bird was to be put, and as there was only one perch—usually a stick or small branch of convenient shape and size—I fondly imagined that the bird would sit pretty nearly where I wished. But I was doomed to disappointment. When I put the bird in, any place and every place suited him better than the perch so carefully arranged for his special comfort. When a bird, no matter how tame he may be, is placed amid new and unusual surroundings, he is at first greatly frightened, and therefore quite unmanageable. It usually requires some time to prove to him that the new cage will not harm him. So I found my cage not altogether a success, but by patience I managed to obtain some very satisfactory photographs.

THE SPORT OF PHOTOGRAPHING WILD BIRDS.

It was not long before I was led to attempt the task of photographing the adult bird in its wild state and in its natural surroundings. It was then I began to appreciate the fascination of the work. Looked at from any one of several standpoints, the photographing of wild birds will be found equally satisfactory. As a sport it should take a high place, for undoubtedly the skill as well as the perseverance and the instinct of the hunter is a necessary requirement, and a successful shot with the camera is far more difficult to obtain than a correspondingly fortunate (on one side only) shot from a gun. Then, too, the accomplishment of one's desire leaves behind it no disagreeable taste to mar one's pleasure. What true sportsman is there (and I speak neither of pot hunters nor "game hogs") who, hearing the death bleat of a deer, does not at heart wish his shot had miscarried? Then, as a means of really becoming acquainted with birds, the camera is without an equal, for to be even a moderately successful bird photographer, one must

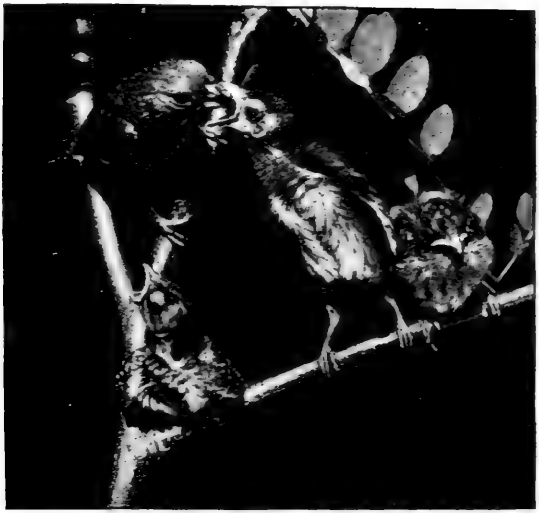
READY FOR LUNCH.

Copyright, 1900, by A. R. Dugmore.

EXPECTATION.

THE OLD METHOD OF BIRD ILLUSTRATION.

From a standard work of natural history.



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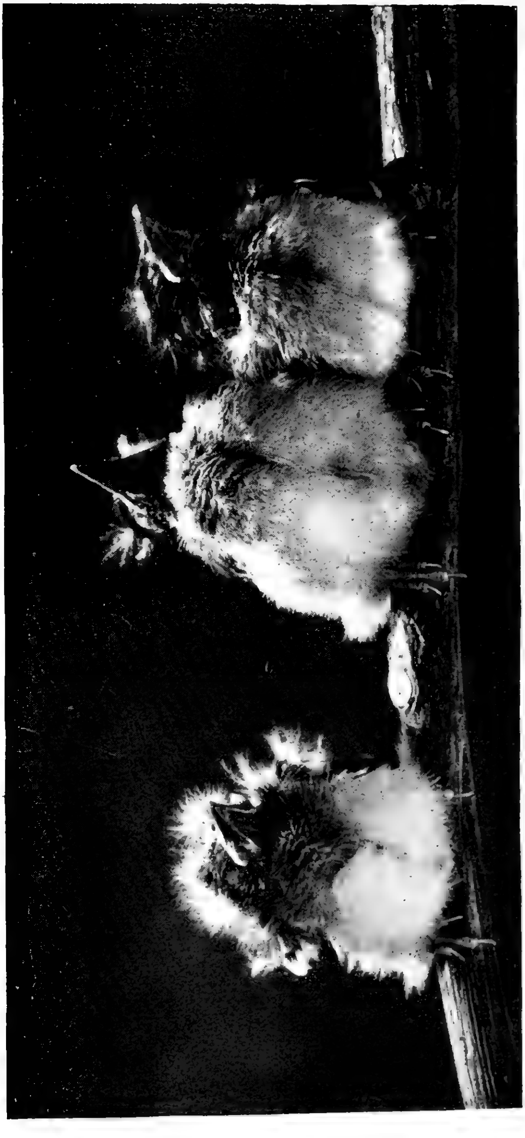
NUMBER THREE BECOMES ANXIOUS.

Three successive snap shots of a wild Indigo bird feeding her young with grasshoppers on a locust tree.

Copyright, 1900, by A. R. Dugmore.

ONE AT A TIME.



Copyright, 1900, by A. R. Dugmore.

A Sleepy Trio (Young Baltimore Orioles).

Copyright, 1900, *by A. R. Dugmore*

ANXIOUS FOR HIS TURN.

The little field sparrows in this picture have been away from the nest only a few hours. The mother bird has brought them a huge grasshopper, and the wild flapping of wings by which the hungry youngster tries to keep his balance is amusingly indicated by the camera, as is also the vigorous protest of his less fortunate brother.

have an intimate knowledge of the subject; and the camera, in teaching us to know the birds, must of necessity stimulate our affection for these useful and defenseless creatures. As a recorder of facts it is of great scientific value, for it can not lie, and it records in an unmistakable form every detail presented, whether it be the daily growth of a nestling or the exquisite detail of the bird's nest.

It is, however, to the keen pleasure that may be derived from this new sport that I would particularly call attention. Not only is there the delight in overcoming difficulties (and they will be found both numerous and varied), but there is the pleasure of being placed among surroundings that are inseparable from this pursuit. A rich harvest of interesting facts relating to the birds' home life may be gathered by any observing person who spends much time along the hedge rows or in the woods.

He who would hunt birds with the camera will find that without doubt the breeding season is the time best suited to his purpose, for then the feathered housekeepers are restricted in their individual range to a comparatively limited area. Having learned the situation of their house, he may find them at home when he calls engaged in attending to their various domestic duties. The first thing to do after the introduction, i. e., learning their name, is to obtain their confidence, and, with birds as with people, there must be confidence if we wish friendship. How easily one may gain this confidence depends quite as much upon the individuality of the bird as upon the species. The fear of man is inherent in all birds, but by judicious management this fear can to some extent be allayed.

WINNING THE CONFIDENCE OF WILD BIRDS.

A great many instances have come before my notice of the change in a bird's behavior from extreme fear and distrust to a degree of confidence which, to the inexperienced, seems almost inconceivable. The power to tame birds or animals is thought to belong peculiarly to certain persons. This may or may not be true, but from my own observations I am inclined to believe that tameness is a quality rather of the natural disposition of the individual, bird, or animal.

With some birds I have spent days in trying to convince them that I intended no harm, yet they placed not the slightest confidence in me, and would not even feed their young if I were in sight. Others of the same species became accustomed to my presence after less than an hour, showing their confidence by coming to their young while I stood in plain sight, within a few feet of the nest. It is in the difficulty of familiarizing the bird with ourselves and the camera that we experience the greatest obstacle to photographing them.

Of the many delightful birds I have had the good fortune to know, the worm-eating warbler family, whose portraits are shown in the accompanying pictures, have afforded me the greatest pleasure, for they become absolutely fearless of the camera, and they place a degree of trust in one that was as unusual as it was delightful. Being anxious to secure photographs of the young, I paid frequent visits to the nest, and what a wonderfully concealed nest it was, tucked away in a small depression and hidden by the roots of an oak sapling. It would forever have remained undiscovered by me had I not by lucky chance observed one of the parent birds visiting it.

Only at first did the owners object to my intruding, and by various methods did they try to coax me away from their home. First one and then the other would feign broken wings, and, half rolling, half scrambling, they would make their way down the steep hillside in the hope of luring me away. Then, finding that I was not to be taken in even by such an artful device, they endeavored to accomplish their object by scolding at me. In less than two hours they quieted down and simply looked on in silence. The next time I visited the nest they made no objection, and I imagined they recognized me and realized that I meant no harm either to themselves or to their young, for these had hatched since my last visit. Day by day I came to watch the little fellows, and they grew rapidly, as all young birds do. Finally they were ready to make their first venture into the great world that, should no accident befall them, was to be their feeding ground for many years to come.

SOME EXCITING EXPERIENCES.

As I looked into the nest the family of fledglings scrambled out as though they had been scattered by some invisible hand, so nearly simultaneous was their action, and in less time than it takes to tell it each little mite of down and rust-colored feathers was hidden among the dead, crackling leaves with which the ground was strewn. Though I had tried my best to watch where each bird concealed itself, it was some time before I collected them all preparatory to photographing them. Of course the parents were greatly excited—birds always are when their young first leave the nest—and when they saw the entire brood captured by one whom they had considered a friend, they seemed to regret having placed so much confidence in me. But only for a very short time did their doubts continue. As soon as I placed the youngsters on a suitable perch they both ceased to utter that lisping note of anxious protestation, and to show that they no longer feared me they hopped about on the camera while I was arranging it.

When young birds (before they can fly) are placed on a perch they invariably fall off almost as fast as they are put on, and there is usually a bad one in the lot who positively refuses to sit anywhere he may be placed. Not only does he fall off, but if possible he grabs one or two of his small companions, and down they go together. These young warblers were no exception, and off they went, one after another.

The bad one proved to be very bad indeed, and he is shown in only two of the many photographs I made of the family.

While these pictures were being taken, one of the parent birds stayed near by to watch over her youngsters, while the other went off in search of food, for which they called continually, and though I was not more than 3 or 4 feet distant, she fed them without troubling herself at all about my presence. Once she even perched on my hat and used the camera as a half-way house, resting on it each time she went back and forth to supply the fledglings with food. Unfortunately the light was not very good for instantaneous photography, but such an opportunity for securing pictures of this comparatively rare bird was not to be missed, so I made many exposures on her and her young, with fair results.

From a photographic stand point they are, of course, faulty, but the subject is sufficiently interesting to warrant one's overlooking these shortcomings. The light had grown so weak by the time I had made about fifteen exposures that I was forced to abandon any further attempts with the camera for that day. Sitting down on the ground, I placed the young warblers on my lap to examine them carefully. Imagine my surprise when both the parent birds came on my knee, first without and then with food for the youngsters. It was quite a novel sensation, and one that was more than enjoyable. It was positively thrilling.

Knowing from past experience how skeptical people are when told of anything that they themselves have not seen, I made up my mind then and there to pay my warbler friends another visit early the following day, and photograph the old one on my hand. The day was fine, and I was fortunate enough to find one of the young ones, who could now fly a little, perched on the low branch of a small bush. One of the old birds was hunting busily for insects. Seeing me pick up her baby, she flew toward me, but did not object in the least to my taking temporary possession of it. So I felt sure that she recognized her friend of the previous day. A few moments sufficed to arrange the camera in a place where the light was bright, and when all was ready to my satisfaction, I took the little fellow, who had been quietly sleeping in the warm sunlight, and set him on my finger.

Soon he called lustily for food, and it was strange to see how quickly his parent heard and understood. In a minute or two she came hurrying along, carrying in her beak a daddy-long-legs, and, after pausing on the camera to see that all was right, she flew on my hand, and calmly fed her hungry little one. With my disengaged hand I pressed the bulb, and a picture was secured.

The daddy-long-legs served only to whet the appetite of my small friend, who cried out eagerly for more. Again the industrious provider went off in search of other and larger insects. She was away for some time but what she brought back fully compensated for the long wait—of perhaps four minutes. It was nothing more nor less than a huge brown grasshopper, nearly as long as the small bird himself. Again was the camera used as a halting place and again did she fly on my hand. Hungry though the little fellow may have been, he was unable to swallow so large a mouthful, and he dropped the grasshopper into my partly closed hand. Unfortunately I had just pressed the bulb and was therefore unable to take a photograph of the interesting proceeding that followed.

Quite naturally the mother bird was anxious that so bountiful a supply of food should not be wasted, and she stood on my thumb and, bending down, so that her head was inside my hand, extricated the prize. Then she proceeded to break it into pieces of suitable size, and with these she fed her quivering and impatient little offspring. During the morning I secured a few more photographs of these interesting birds, and then returning the youngster to the bush whence I had taken him, I left the pair in possession of their hillside estate.

SOME INTERESTING DISAPPOINTMENTS.

I then went to pay a visit to an ovenbird whose beautiful dome-shaped nest was hidden among the dead leaves in the woods near by. She was at home when I called, so I decided to photograph her. Unfortunately the roof of the arched nest cut off the light so that under existing circumstances a good picture could scarcely be hoped for. A small looking-glass, however, served to alter things, by throwing the sunlight into the nest, so that only a very short exposure was necessary.

My mind was fully made up to make the further acquaintance of this little thrush-like warbler after the arrival of her brood, for it is then that one can really know a bird. The day arrived, and the four little trembling pink bodies had taken the place of the speckled eggs. They were too small to photograph then, so I left them for two days and then made one photograph, thinking that later on, as they grew stronger, I should be able to photograph them at different stages of their growth. But this was not to be. As I approached the domed nursery I was greeted by the pitiful complaining note of the pair of ovenbirds. That was not the way in which they usually greeted me. I feared the worst, and my fears were realized. In place of the nest there was only a tangled and shattered heap of weed stems and dry leaves—the materials that but a few hours before had constituted a beautiful example of bird architecture. In the soft earth, within 30 inches of the ruins, was the print of a cat's foot. Sick at heart, I left the scene of misery and desolation, vowing an awful vengeance against cats in general.

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A WOODCOCK ON HER NEST.

The protective coloring of the bird is admirably shown—even in this black and white picture. Even the bill is thrust under a stick, so that it looks like the surrounding dried twigs and grasses.

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A DISREPUTABLE PAIR.

Screech owls, photographed from life.

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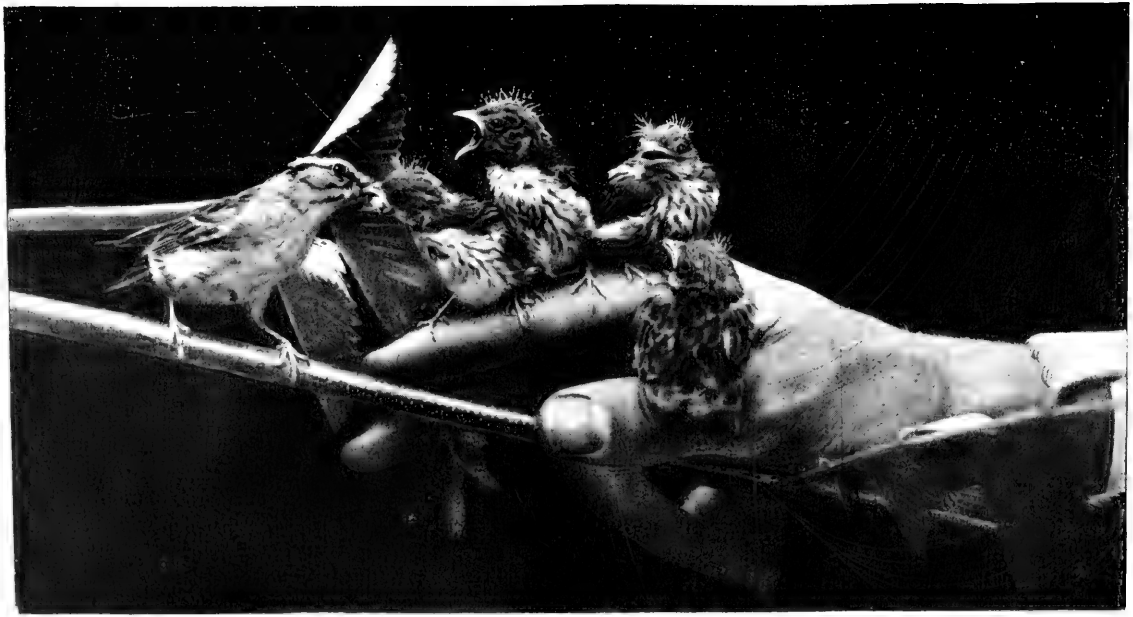
SCREECH OWLS.



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A BROOD OF WILD CHIPPING SPARROWS.

Photographed on the author's hand by himself, using an air bulb and long tube. The mother bird is feeding her young, and the other parent flew just as the exposure was made, his tail being shown at the top of the cut.

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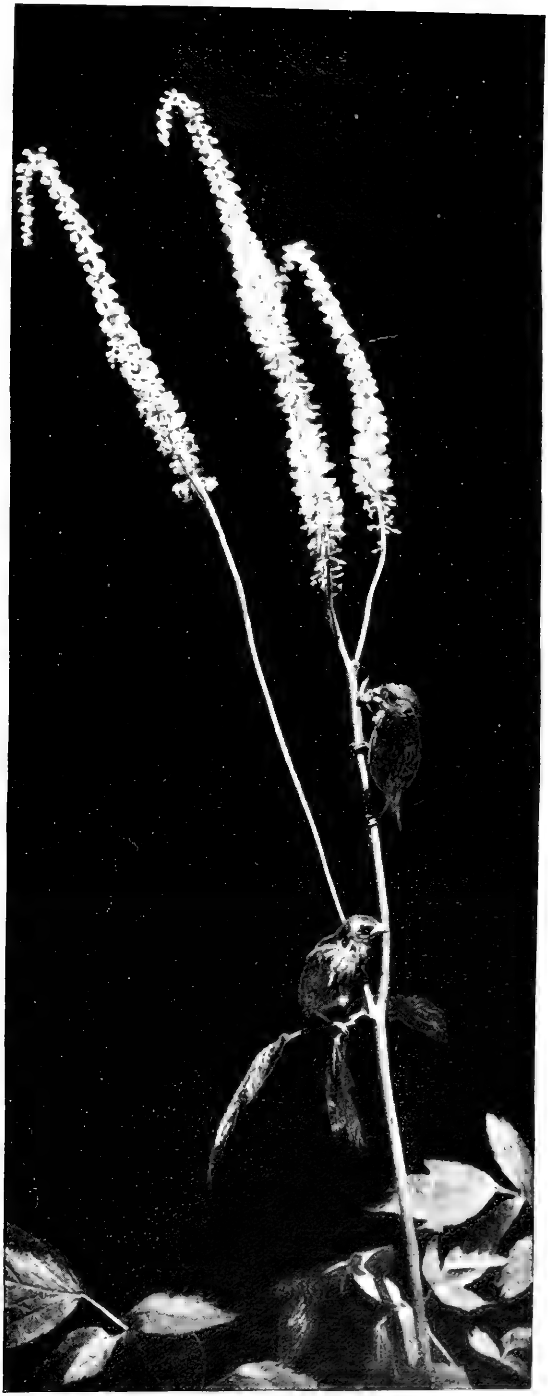
BRINGING HOME PROVISIONS.

Female Indigo bird, on stalk of Queen's lace



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THE SAME INDIGO BIRD (SEE PLATE VIII) AND ONE OF HER CHILDREN, ON STALK OF BLACK COHOSH.

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SCOLDING THE INTRUDER.

A wild, worm-eating warbler, taken as she protests against the author's proximity to her young.

PHOTOGRAPHING NESTS AND NESTLINGS.

To photograph the nest containing eggs is usually a comparatively easy matter, as a long exposure may be given. The best results are obtained when a gray day is chosen, as the light is softer and more diffused, so that all the details, both of nest and eggs, are clearly shown. A very different task is the photographing of the young in the nest, and the resulting pictures are seldom what one hopes for. The reasons for this are obvious. The young are never quiet even when asleep, owing to their rapid respiration. This precludes a time exposure, and this in turn prevents the use of anything but a large diaphragm; therefore, as the distance from the near edge of the nest to the bird farthest away is several inches, only a small part can be in focus, while the rest is a blurred mass. If the light is sufficiently bright, the best results may be obtained when the nestlings raise their heads for food, as each bird is then more clearly defined, instead of being part of a shapeless, heaving mass. This applies more particularly to the photographing of small birds, as the camera, with a lens of ordinary focal length, has to be placed very near the nest, with the consequent lack of depth of focus that is unfortunately inseparable from such conditions.

To photograph the parent bird sitting is difficult or easy, according to the disposition of the bird, which varies not only with the different species, but with individuals of the same species. Usually the brown thrasher, the wood thrush, or the catbird, will sit close, and allow the camera to be placed within a few feet of them while they are on the nest; but I have seen exceptions, which go to prove that success depends largely upon the peculiar disposition of the bird itself. People think as a rule that, because a bird builds its nest in the immediate vicinity of a house, it is necessarily tamer than one that chooses the quiet seclusion of the woods. This has not been my experience, for the tamest birds I have ever known were those that nested in places comparatively remote from human habitation.

When the fledglings leave their nest, the bird photographer should be on hand, for then it is that he can obtain the best pictures, as the youngsters may be put on any perch that best suits his fancy, and a place where there is sufficient light may be chosen. For the benefit of those who might wish to try their hand at this fascinating branch of photography I give the following suggestions:

SPECIFIC DIRECTIONS.

Select a branch or briar of suitable shape and size—and young birds prefer a fairly thick perch. This should be arranged so that it will not be swayed by the wind, lest the branch move and the birds be out of focus. Bright sunlight is necessary, as the exposure must not exceed one-fiftieth of a second. With such a short exposure the shadows are likely to be lacking in detail, so it is advisable to place beneath the birds a white cloth, and this should be tilted to such an angle that the reflected light shall strike those parts of the birds that are in shadow. If the natural background is not strongly sunlit, it will be an advantage to use a white or light-gray cloth as an artificial background, but it should be placed at a reasonable distance from the birds; from 4 to 8 feet will answer. Now place the little fellows on the perch and arrange the camera, remembering—if you wish to photograph the parent bird with her young—to leave sufficient space between the young birds and the edge of the plate, so that no matter on which side the old one comes to feed them the camera will be in readiness. All that remains to be done is to attach a long rubber tube to the shutter. Then sit down in an inconspicuous place and wait patiently until the old birds have fully convinced themselves that no harm is intended. Then they will venture near the camera and feed their hungry young.

Any one who uses the camera as a means of studying bird life will undoubtedly be surprised to find how marked is the individuality of birds. Not by casual observation does one discover this, but in the intimacy with the birds that one acquires when one watches for hours at a time the bird upon whose nest or young one may happen to have the instrument focused.

A camera, to be rigid and sufficiently durable to stand several seasons of field work, must be fairly heavy, though not of necessity large. A sufficient size for most work is 5 by 7 inches, while some even prefer one as small as 4 by 5. This latter is correct in size and proportion for those who wish to have lantern slides made from their negatives, and is certainly far better adapted to all whose enthusiasm is limited, and who do not wish to overburden themselves.

For my own part I use the 5 by 7 almost exclusively, and frequently I wish it were larger, particularly when the subject to be photographed is the parent bird feeding her young after they have left the nest. Place four or five fledglings on a branch, leaving sufficient space on either side to allow the old bird to stand, and reduce all this interesting material down to a 5-inch space, and you will realize the advantage of even the extra 2 inches allowed by the 5 by 7. How many times has it happened to me to have the father or mother bird perch just outside the limits of my 5 by 7 plate, and assume some attitude that I was most anxious to catch; and again how often has the plate through its limited size cut off part of the adult bird. In such cases I long for my larger camera which, on account of its weight, has been left behind.

PHOTOGRAPHING WILD ANIMALS.

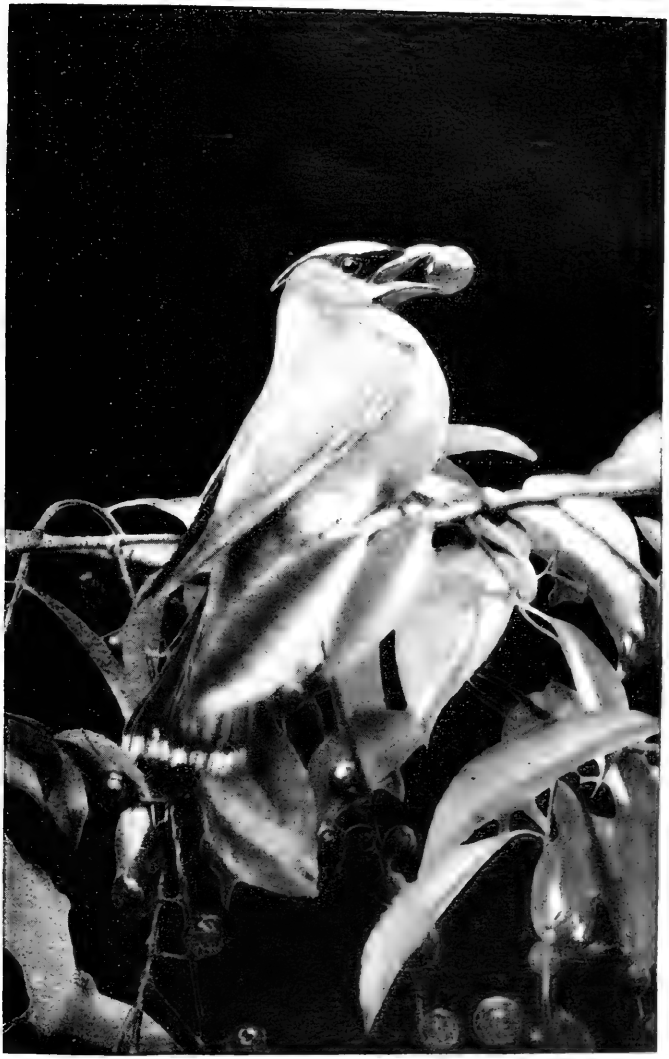
Turning now from pictures of birds to pictures of animals, we find that, owing to the difficulty of obtaining good photographs, drawings are still used almost exclusively. The field for camera work here is enormous, but unfortunately the difficulties are so numerous and overwhelming that good results are obtainable only after almost endless labor, and but few can give the necessary time. Of course this refers to animals in their wild state, but there is another field that has been as yet only lightly touched, and that is photographing animals that are in captivity. This is a task that is comparatively easy; but if really good pictures are desired, it will not be found quite as simple as one might believe.

The three essential things to be considered are: First, the pose of the animal. This is extremely important, as a position should be chosen that is characteristic of the species. Secondly, the arrangement of the surroundings. A bad foreground will surely ruin a picture; so, also, will the introduction of a fence or any similar object in the background, and the greatest attention should be given to the composition as a whole. Thirdly, the light. This is important, for it will make or mar the picture. When a very short exposure is given, the fewer shadows there are the better will be the result; but in cases where an ample exposure is possible, the light may be arranged entirely with regard to the pictorial effect. It will be readily seen that the mere snapshot has no more place here than it has in live-bird photography. A good picture, whether made with a camera or the pencil, is the result of study and careful arrangement, and only in very rare cases is it the result of chance. The several photographs of prairie dogs here shown were made in the National Zoological Park (Washington), but, so far as the backgrounds and surroundings are concerned, they might well have been taken on the great prairies of the West.

Up to the present time my experience in photographing wild animals in their native haunts has been very limited. The animal to which I have devoted the greatest time is the Canadian porcupine. For nearly two weeks I stayed in the Adirondacks where they are abundant, and during that time I made photographs of these prickly fellows in nearly every possible position—on the ground, in trees, and in the water.

The accompanying photograph of the woodchucks is a fairly lucky shot. Unfortunately the animals' feet are nearly hidden by the light white sand excavated from the burrows; but one must overlook such small defects in pictures that are so difficult to obtain. This photograph was taken while I was looking for porcupines in the Adirondacks.

The picture of Mrs. Mouse (white footed) and her family is another of the lucky shots, so few and far between.



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CEDAR BIRD EATING WILD CHERRIES.

This gourmand, of course a wild bird, was caught just as he had picked a luscious cherry, and was about to toss it in the air preparatory to swallowing it.

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PRAIRIE DOGS.

These very shy little animals were photographed at the Zoological Park, Washington, after repeated trials and the exercise of infinite patience on the part of Mr. Dugmore. They have a way of disappearing at the least motion which is eminently disconcerting to their would-be portrait makers.

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HESITATION.

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READY TO DISAPPEAR.

Photographed at the National Zoological Park, Washington.

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A WILD PORCUPINE.

Photographed in the Adirondacks.

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A PAIR OF WOODCHUCKS AT THE ENTRANCE TO THEIR BURROW.

This photograph from life, as are all the others in this article, represents a hard day's work in the Adirondacks, and a good deal of luck even at that. The size of the animals indicates the closeness of the camera, which was concealed in the bushes not more than 6 feet away.

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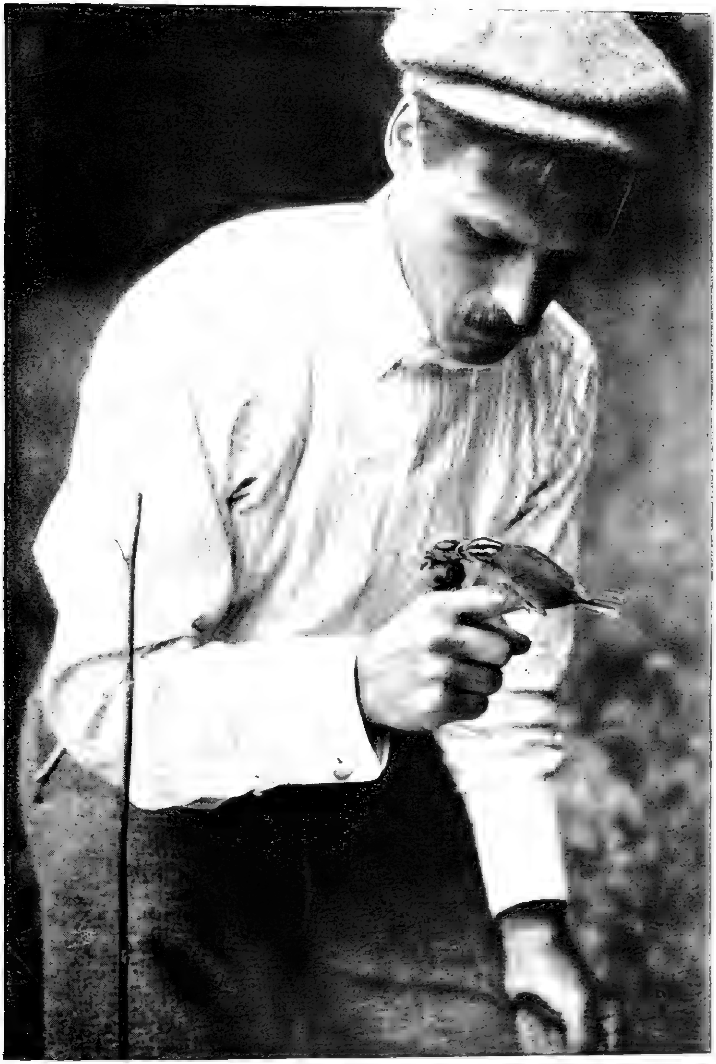
A WHITE-FOOTED MOUSE AND YOUNG (ABOUT LIFE SIZE).

While out for a walk with a friend, the author came across this interesting group. The frightened mother instantly disappeared, and could not be found after the most careful search, only after reaching home did Mr. Dugmore's companion find the poor little creature *in his pocket!* Fearing lest the young ones would die, the author ran back 2 miles with the old mouse in his hand, and managed just before dusk to secure this picture of the first meeting of the reunited family.



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THE AUTHOR PHOTOGRAPHING A WILD BIRD ON HIS HAND.

This worm-eating warbler was a wild bird which Mr. Dugmore in a few days got so used to his presence that she would bring her young food while on his hand. At the proper moment the bulb of the rubber tube running to the camera was pressed with the left hand.

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ROCK BASS.

Photographed through water—the first successful negative made by the author, after a number of experiments.

THE OUTLAW; A CHARACTER STUDY OF A BEAVER WHO WAS CAST OUT BY HIS COMPANIONS.[1]

By A. Radclyffe Dugmore.

[Mr. Dugmore's extraordinary photographs of wild birds and animals in their daily occupations have already attracted much attention. He seems to have a peculiar faculty, like Thoreau, of making friends of all sorts of wild creatures; in two days in the woods, for instance, he will get such a wild bird as a worm-eating warbler so accustomed to him that she will feed her young on his hand, having her picture taken at the same moment! This story is the first of a series which will give 'character studies'' of different animals with whom he has become acquainted, along with reproductions of the author's surprisingly lifelike and interesting photographs. It is the most intimate and illuminating sort of natural history. The pictures reproduced herewith are particularly notable, as they are perhaps the first good photographs of beaver ever secured, the nocturnal habits and shyness of these animals making them peculiarly difficult subjects for the animal photographer.—Everybody's Magazine.]

It would be difficult to imagine a more pathetic sight than that of this poor old beaver, living in a land of many animals and yet so entirely alone; within sight of his comrades, yet not among them; unable to join in their games and their work, living his lonely life like a prisoner, within sight and sound of his fellow-beings, but separated by a barrier as strange as it was secure. This was the animal that appeared after I had been watching for an hour or two in the beaver inclosure at the Washington National Zoo. There was a movement in front of the large burrow opening on the water, and a head peeped cautiously out, to see that all was safe for the owner's regular evening exercise. The sun had long since disappeared behind the hill, and everything had the quiet hush of evening. The deep roaring of the lions and tigers, and the more distant barking of the seals, alone disturbed the silence, when the beaver believing himself to be alone, plunged noiselessly into the water, dived beneath the log that lay partly submerged but a few feet from the entrance of the burrow, and reappeared in the middle of the small pond.

Almost like a short piece of driftwood he lay, his dark, bead-like eyes gazing intently at me, where I stood in the shadow of a small

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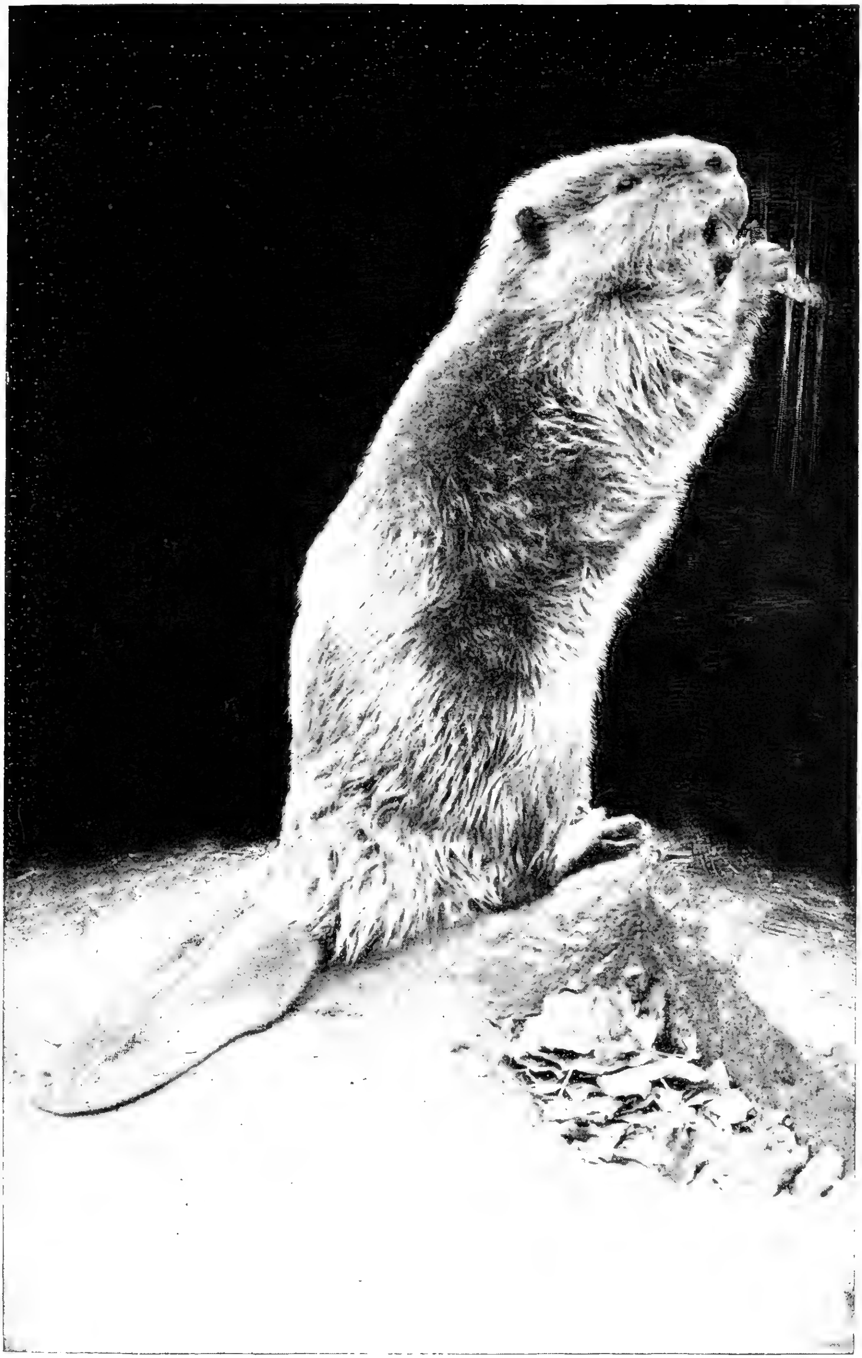
tree. Observing no movement, and not being of a suspicious nature, he soon swam ashore, and immediately walked, moving for all the world like a large, smoothly coated Canadian porcupine, straight to the corner of the fence that separated him from his relatives. Once there, he stood on his hind legs and tail, and with front feet resting on the horizontal bar, he gazed with a longing, wistful expression at the lodge in which the other beavers lived. Never surely was loneliness shown more eloquently than by this animal as he stood there, the very picture of solitude. For ten minutes he remained thus, motionless except when, as though no longer able to endure his misery, he would bite the hard, cold bars of iron, as he had bitten them every evening during three long weary months. Did he imagine that, perhaps, some day he would find the bars had softened and would yield to his chisel-edged teeth—teeth that, were he in his native wilds, would work their way through anything save the stones or the cruel metal of the steel trap?

Wishing to examine more closely this interesting animal, I approached quietly, hoping not to disturb him; but he felt uncertain of my intentions, and before I had lessened the distance between us by more than a few steps, he dropped on all fours, and after regarding me curiously for a minute or two, turned and made for the water. Once there he felt more secure. Usually at the least sign of danger he would slap the water loudly with his large, flat tail as a warning to his friends, and then instantly disappear from view and retreat to the privacy of his gloomy burrow. This time, as the danger did not appear to be imminent, he contented himself with diving silently, coming to the surface at the farther side of the pond, from which place he watched me.

Soon, however, his curiosity got the better of his natural timidity, and he swam back toward his regular landing place, which was as clearly defined as an otter's slide. He swam slowly, stopping repeatedly as though in doubt of his visitor's intentions. Suddenly, and with no apparent reason, he concluded there was no cause for fear, and immediately came forward, landing within 2 feet of where I stood. Once on shore, he again doubted the wisdom of his course and hesitated, not quite liking to pass so near a human being. Sitting half erect on his hind legs, with his small forepaws held close beneath his chin, he carefully watched me, while his nose moved slowly, as though he were trying to scent an enemy.

A few minutes sufficed for this examination, by which we established a certain degree of mutual confidence at once pleasing and useful, for I hoped on the following day to take a few photographs of this newly acquired friend, and of course it is highly desirable that one should be on a footing of trust with one's model, especially when the latter has the retiring disposition of the beaver. It was rapidly



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THE OUTLAW.

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THE BEAVER'S LODGE.

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"THE LODGE IS OUTWARDLY A MASS OF LOOSE STICKS."

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THE BEAVER INCLOSURE AT THE WASHINGTON NATIONAL ZOO.

becoming dark—too dark, indeed, for me to distinguish much more than the general form of the animal; so I left him to his thoughts, intending to visit him again before the next setting of the sun.

When the beavers were brought to the Zoo, they were given for their new home an inclosure of perhaps 2 acres. This was part of a very small but well-wooded valley, through which ran a stream of insignificant size. It was so small that the beavers were unable to swim in it, so they immediately commenced building a dam. To do this, the trees, which up to this time were unprotected, were felled by these industrious little woodcutters and engineers and the branches cut into convenient lengths so that they could be pushed or carried to the scene of their operations. These branches formed the main part of the dam, while mud and roots dredged from the bottom of the stream were used to fill in the holes, and render the entire structure water-tight. The upper part was carefully covered with mud which was carried there in the animals' hands. To realize fully how much work this required one must see for himself this dam, which contains probably more than 30 tons of material.[1] It was soon found necessary to protect the trees still remaining uncut (no tree of ordinary size is safe from the beaver's teeth, stumps of trees 2 feet in diameter being frequently found cut down by them), and these were covered near their bases with heavy wire netting. But the beavers, nothing daunted, succeeded in cutting into the wood in spite of this precaution; so the netting, supported by iron rods, was finally placed at a distance of several inches from the tree trunk. In this way the trees were saved, but the beavers still needed building material, as the dam was not yet large enough to make their pond as they wished it. More branches were therefore supplied, and cartful after cartful was used up before the main dam and the three auxiliary dams were completed. It was late summer by this time, and there was still a house to be built, and that, too, with as little delay as possible. With the arrival of cold weather all building operations must cease, as the mud becomes frozen and too hard to work. The house, or lodge, as it is more properly named, is outwardly a great mass of loose sticks, some of which from their size might be called logs, filled in with earth and roots and plastered over with mud. In the center there is less mud, the sticks and twigs forming a partly closed flue, which serves as a ventilator. Inside the house all is darkness: the walls are rough, but the floor, which is raised a few inches above the level of the water, is firm and smooth, of fine twigs beaten into the earth. The entrances—for there are usually two or more—are several feet beneath the surface of the water. What impresses one on seeing the lodge and dams built by the beavers in the Zoo is the fact that in no way do they differ from those found in the most remote parts of Canada.

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[1] This is but a rough guess, and is probably far short of the actual amount.

With the arrival of spring it was found that the beavers had increased in numbers, very much to the delight of all concerned; but the following year, when they were all full-grown, the rules and regulations of beaverdom were put in force. It was decided that there was one beaver too many, and according to their laws he must either betake himself to some other locality or submit to an untimely death. Now, the victim chosen—whether by ballot or by what other means, who shall say?—was our old friend, and as it was impossible for him to leave the colony of his own accord, death would have been his lot had he not been saved by the keeper. For a short time he was kept in a cage, until a suitable place could be made ready, and the place selected was the inclosure in which I found him leading his lonely life.

Being a solitary bachelor, he had not as yet gone in for regular housekeeping. Perhaps he thinks it scarcely worth while building a house until he has a mate. As it is, he has made a burrow in the bank with the entrance at the level of the water. In this he spends his days, seldom coming out at all before sunset, and frequently much later. On leaving his underground house he invariably goes directly to the fence corner, where he stands watching his former companions for as much as half an hour at a time. They, on the contrary, seldom pay the least attention to him.

On the occasion of my second visit I brought my camera, though I was told how little chance there was of being able to secure photographs of him, and certainly the conditions were far from being favorable. It was nearly 5 o'clock (November 1) before he made his appearance, and then, as on the previous day, after emerging from his underground home, he lay, log-like, on the water, taking in the situation before venturing ashore.

After satisfying himself that all was well he landed, and walking past the camera (which had been placed in position on the chance of his following his usual routine) took his place at the fence corner. There he stood erect as on the previous day, watching vainly for his old playmates, who had not yet made their appearance. From their lodge came the sound of muffled voices. Evidently they were holding an animated conversation in beaver language. It is a strange-sounding tongue—like a mixture of subdued children's voices and the crying of a very young puppy. Whether or not our beaver understood the drift of their discussion would be difficult to say, but certain it is that he seemed to be very much interested by it all.

While he stood there, showing no sign of movement, I was able to make several exposures, bringing the camera nearer each time. When within about 5 feet he turned around to examine the queer one-eyed machine that approached so quietly on its three legs. Evidently he was puzzled, without being frightened, for after a few seconds' delib-

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"FOR ALL THE WORLD LIKE A LARGE, SMOOTHLY COATED CANADIAN PORCUPINE."

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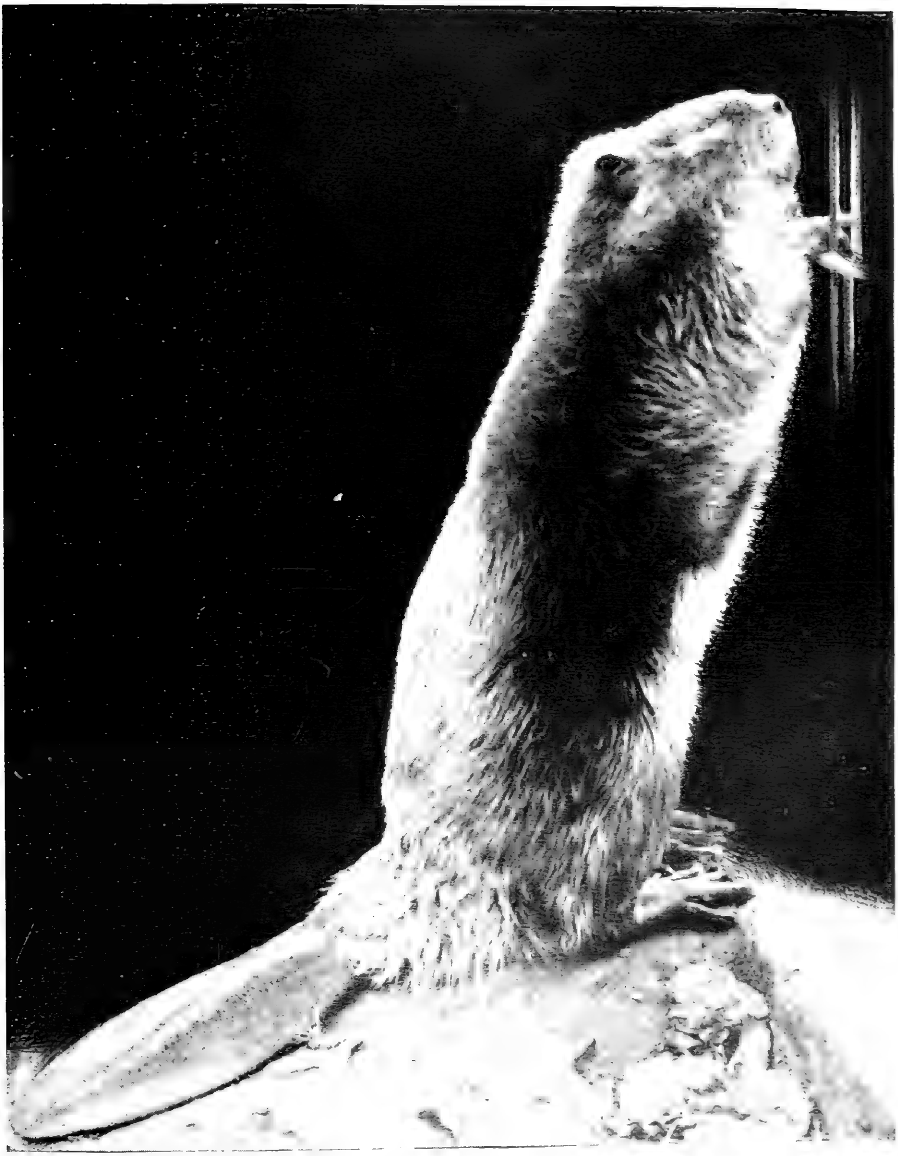
"HE WOULD BITE THE HARD, COLD BARS OF IRON."



"GAZED WITH A LONGING, WISTFUL EXPRESSION AT THE [illegible]
BEAVER HOUSE."

Copyright, 1900, by A. R. Dugmore.

"HE DISCOVERED A NICE GREEN STICK ON WHICH SOME OF THE BARK STILL REMAINED."

eration he decided to satisfy his curiosity by coming straight for the camera, slowly at first and hesitating slightly at each step. Each leg of the tripod was carefully scrutinized and found to be harmless; so, resting his hands on one of the tripod legs, he raised himself and took a good look at the camera itself. His nose must have discovered some new odor, for he sniffed at it, first on one side, then on the other.

Presently his attention was attracted to the rubber ball belonging to the shutter. This was swinging at the end of the tube, and he thought that, perhaps, it was something new in the way of food. In another moment the bulb would have been rendered useless, as it would have been quickly punctured with his sharp teeth. At this critical moment I had to interfere, very much to the old chap's disgust.

Wishing to make friends with this strange animal, I sat down near the camera. At once he came so close that I could put my hand on his soft, furry back, wondering at the same time what would happen if he should take it into his head to use his teeth, for with their extraordinary strength and sharpness the amputation of a finger or two would have been the work of but an instant. There was, however, no need of fear, as he was a very well-meaning old fellow, and contented himself with walking slowly round me, stopping occasionally to sit on his hind legs and take a general survey of the curious being who went about with such a queer three-legged companion.

Satisfied that he might safely leave me for a short while, he went to his corner, and after looking for a few minutes at his neighbors, who were swimming about in their pond, he walked down his path to the water's edge and in his own peculiar, noiseless way plunged in. Very soon he discovered a nice green stick upon which some of the bark still remained. This he brought into shallow water, and, holding it with his two front paws (hands they should perhaps be called), proceeded to make a meal off the bark. This may seem a very unsatisfactory sort of supper, yet he enjoyed it. But a few minutes were required to strip the stick, after which, as he had no house to build, it served no further use and was left in the water, while the animal swam round the pond, making a tour of investigation, which resulted in his finding nothing more that was suited to his taste. So coming ashore, near where I stood, he commenced his evening toilet.

This was an interesting sight to watch. To begin with, instead of sitting with his large, flat, ribbed tail protruding behind him, he tucked it forward between his hind legs and sat upon it. Then with his hand he carefully combed his long hair, using both hands at the same time. There were many places, however, that could not be reached in this way, for his arms are very short and his body very large; so he combed these otherwise inaccessible places with his hind feet, using first one and then the other. The entire operation was performed with the utmost deliberation and care, and occupied more than a quarter of an hour, so that by the time it was completed daylight had almost vanished. My presence did not appear to disturb him in the least, though I sat on the ground within 3 feet of him, that I might the better note his various attitudes, for it is not often one has an opportunity of watching a beaver at such close range.

He had just completed his toilet when the night watchman, whose duty it is to feed the nocturnal animals, arrived with a basket of stale bread and fresh vegetables. These he threw into the inclosure, the vegetables on the bank, and the bread into the water. Mr. Beaver well understood the meaning of these splashes, and as soon as the keeper had disappeared he plunged into the water, utterly regardless of his newly dried jacket, over which he had taken so much trouble, and seizing one of the half loaves of bread in his hands, swam to a shallow part of the pond to eat it. He first held the loaf in his hands, much after the manner in which a squirrel holds a nut; but the soaked bread fell apart, so he made a bowl of his hands and lapped the wet crumbs out of it. In this way not a particle was lost.

Piece after piece of bread was eaten in this manner, when he came ashore and made short work of the carrots and potatoes. It was quite dark by this time, and as it was impossible to see anything more, I was obliged to leave him, with the hope that in the near future I might continue the acquaintance so pleasantly begun. By that time, let us hope, he will no longer be solitary, but will have taken to himself a mate whose disposition will be as good as his own; then a house will be built, and the two will live as well-regulated and happy beavers—and human beings—should.

A NOTABLE ADVANCE IN COLOR PHOTOGRAPHY.[1]

"It is now possible for a newspaper correspondent in China to take snap shots in his ordinary camera, fitted with a newly perfected screen; to send the negative to New York, and there have the picture reproduced in all its original colors, the printer having no previous knowledge of the colors themselves."

This is the somewhat startling claim made by two American inventors, Mr. C. L. A. Brasseur and Mr. Sebastian P. Sampolo. A sample of their work showing the progressive steps of the method will be found as a special insert in this issue of The World's Work. It opens up a whole new world of possibilities in the field of illustration, the modern development of which has been one of the seven wonders of our time, though we who are in the midst of it all hardly realize the fact. In an hour to-day anyone with eyes can learn more about the externals of China and the Chinese, for instance, than would have been possible by any conceivable means short of a visit to that country twenty-five years ago. The causes are improved photographs and the consequent extension of illustration in newspapers, magazines, and books.

But so far as color is concerned we are almost as badly off as our forefathers. The camera is not only inefficient, but often an astounding liar in its reports of the colors upon which it looks; and the successful accomplishment of what Messrs. Brasseur and Sampolo believe they have done would soon work most revolutionary changes in the matter of making pictures.

Every reader of current magazines and books is familiar with the results of what is known as "three-color work."

With all its present shortcomings, this process may fairly be credited with having done more than any other influence to give us satisfactory colored pictures at a reasonable price. Truth of form it achieves absolutely, photographically; and its defects are due to the mechanical difficulties of applying an absolutely correct theory.

[illegible]e-color work has limitations that have greatly hampered its development. Roughly speaking, the process consists in making three different half-tone negatives through as many colored screens—that is to say, the object or painting is placed before the camera as if an ordinary black and white half-tone (the usual sort of magazine illustration nowadays) were to be made; but between the lens and the half-tone screen is placed a piece of glass of a peculiar yellowish color;

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[1] Reprinted, by permission, from The World's Work, December, 1900.

and then from this negative a printed block is made by the usual method. A second negative is made through a screen of red glass, and a third through a blue screen, plates being similarly obtained from each. By printing the plate made through the blue glass in yellow ink, that made through the yellow screen in a reddish ink on top of it, and the third in a blue ink on top of these all the original colors are produced.

Such at least is the theory, and when proper pigments and exact registration are employed the results are beyond criticism.[1]

As can be seen, this method is most cumbersome and the picture or object to be reproduced must be taken to the engraver's gallery. The exposure for the blue plate alone requires from five to thirty minutes (a year or two ago it was frequently over an hour), and the other colors take from thirty seconds to three minutes additional. Of course this limits one to a very restricted range of subjects.

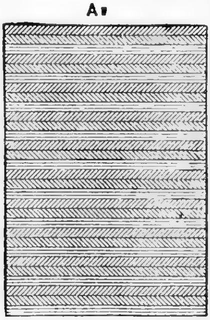

FIG. 1.—B (A enlarged 53 times). Positive on glass made from original negative; successive groups of colored lines, each color repeated every third line.

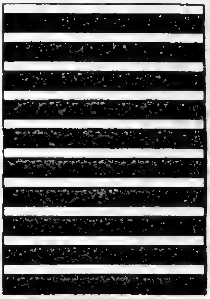

FIG. 2.—The black and white screen used to pick out each positive; each black line equal in size to two colored lines.

Spot marked A is the exact size of a spot on the negative, of which B is an enlargement. That spot is on the screen occupied by 30 colored lines in exact juxtaposition, each line transmitting certain wave-lengths of light in definite proportions. Screens as large as 8 x 10 have been made, ruled in this fashion.

By this newly perfected process, however, only one negative need be made. It requires an exposure of only from one-tenth to one-sixtieth of a second, and the three plates into which this original is subdivided are just as accurate as those made by the old awkward plan. For the first time, therefore, photographic color prints of moving objects are possible.

What these inventors have done is to make a commercial possibility

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[1] As an instance of the difficulties, it may be stated that the only color known which gives approximately the luminous purple-red needed is rhodamine, one of the coal-tar colors; but unfortunately this fades in a few hours. So the printers have to use the next best, a bluish red, which is by no means exactly right.

of an old theory by ruling glass screens with infinite fineness and accuracy and in breaking up the original negative into three, from which plates can be made to print on ordinary paper.

All makes of ruled polychrome screens can be used to obtain the necessary negatives for the Sampolo-Brasseur process. The best are those ruled in lines in groups of threes, one line being in a reddish orange color, one in a yellowish green, and the other in a blue-violet color. These colors may vary somewhat, as the dry plates of different makers are not equally sensitive to the various colors of the spectrum. In case of a serious departure from these colors, corresponding changes must be made in the printing inks used.

The screens made by Mr. Brasseur have 531 lines per inch, with no mistakes in any inch of more than one fifty-thousandth of that space.

Having obtained the necessary negative, a positive on glass is made.

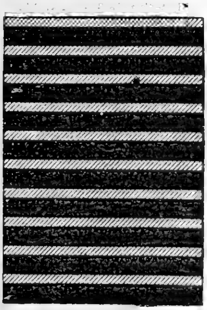

FIG. 3.—Black and white screen placed over positive and showing only one of the positives.

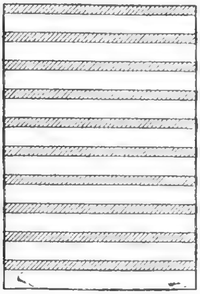

FIG. 4.—First step in making negative. Only one-third of the plate is covered, and prints from this could not be properly superposed.

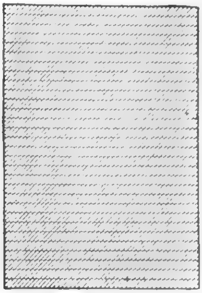

FIG. 5.—Completed negative of one of the images. Entire surface is now occupied by image which on original only occupied one-third.

This positive is apparently no different from ordinary positives, but if it be examined under a microscope it will be found to consist of three interwoven images, corresponding with the three sets of lines of the taking screen. (See Fig. 1.)

Suitable printing plates must now be made from each one of these interwoven images. This is done by placing a black and white screen (fig. 2) over the positive in such a way as to hide two of the images and leave only the third one visible, say the yellow. (Fig. 3.) A half-tone negative is made of this (see fig. 4), and during the exposure the most important step occurs; the negative plate (see fig. 4) is moved continuously until the image which occupied the one-third of the plate occupies the entire surface. (See Fig. 5.)

This is essential, as to obtain the proper colors the prints must be superposed and not juxtaposed, as they were in the original positive. The screen (fig. 2) is now shifted the width of one line, covering up the image of which a printing plate has been made and exposing a new image, say the red one. A plate is made of this one and the operation is repeated for the third image—the blue one.

Not only does this new method give an infinitely extended range to color photography, but the black and white prints are far superior to ordinary ones, as the color values are reproduced with absolute fidelity. In an ordinary photograph of the American flag, for instance, the blue would come almost white and the red black—a falsification of values entirely corrected by the Sampolo-Brasseur method.

1. THE ORIGINAL PRINT.

2. THE YELLOW PLATE

3. THE RED PLATE

4. RED AND YELLOW COMBINED

5. THE BLUE PLATE

6. COMBINATION OF THREE COLORS

A TIGER

Photographed at the National Zoological Park, Washington, D. C.

THE BREEDING OF THE ARCTIC FOX.[1]

By Henry de Varigny.

The taxonomic position of the arctic fox has been the subject of a good deal of discussion, which perhaps is not yet closed. It appears, however, that, for the naturalists, at least—the furriers thinking differently—there is no doubt about the matter; the arctic fox, being a perfectly characterized species, *Vulpes lagopus*, the *isatis* of F. Cuvier and Gmelin. On this point authorities agree, such as St. George Mivart, in his monograph on the *canidæ*, and our distinguished collaborator, Truessart, in his Catalogus Mammalium.

The arctic fox inhabits the Arctic zone, Spitzbergen, Greenland, northern Siberia, Nova Zembla, and the northern part of North America; in short, the extreme northern parts of both the Old World and the new.

The species is curious in several respects. Of all the *canidæ* it is probably the only one which, in certain regions at any rate, performs regular migrations, as Richardson's observations show that it does. The arctic fox is said to live in societies or communities of twenty or thirty families, in groups inhabiting the same number of holes or burrows in one neighborhood. In winter they go south, driven away by the cold and by the consequent scarcity of food, keeping usually near the coast. According to Parry, they begin to quit Melville Peninsula in November. In January very few remain behind. The southern limit of their migration varies. Along the coast they advance farther than they do in the interior, sometimes reaching north as far as the parallel of 65°, and they have been seen as far south as 59°, exceptionally even at 53°. Like other foxes, they are carnivorous. But what game can they find in winter? The birds of passage are gone. Not one is left. Yet the arctic fox does not hibernate. He retains all his activity throughout the long polar night, and to sustain this activity he must get food. Mr. Alfred Newton, who observed these foxes in Spitzbergen in 1863, asked himself whether they did not perchance lay up provisions during the fine season. But if so, where would these

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[1] Translated from Revue Scientifique, 4th series, vol. 14, September 22, 1900.

hidden stores be, which nobody had ever seen? One day Mr. Newton came across a heap of shells of fresh-water mussels, *Mya truncata*, in the moraine of a glacier, and it occurred to him that it might be the *kjökkenmödding* of some fox, the leavings of his winter meals. He thought that foxes might very likely store up in summer some provisions, mussels for instance, which they would use in winter.

This hypothesis has been amply confirmed, at least in certain respects. It is evident that if the arctic fox made sufficient provisions, he would not have to migrate in winter. But, on the other hand, it is certain that he gathers enough to last him for some time. H. W. Feilden put this beyond doubt in 1875, during the Nares expedition. Having shot a fox, he noticed that little lemmings came out of their holes all about, and began nibbling leaves and blades of grass. But there were also quantities of dead lemmings, and these had died violent deaths, namely, from a fox's bite in the skull. Looking nearer, adds Feilden, he was surprised to find numerous accumulations of dead lemmings; in a corner, a little way off under a rock, he found a pile of more than 50 of them. Caches of 20 to 30 carcasses each were numerous; and the ground was pierced with many holes, each containing several carcasses of lemmings covered with a little earth. One hole he found to be stuffed with the greater part of a hare. Here is an interesting case of reciprocal action. For where the caches of lemmings were numerous the ground was, of course, richer in fertilizing matter, so that the vegetation was more abundant, and this relative exuberance of vegetation, of course, attracted more lemmings. Thus, the behavior of the foxes favored the multiplication of lemmings about their burrows; and they could not have contrived anything more ingenious if they had acted deliberately.

The arctic fox is not astute. In this respect he is markedly inferior to his cousin of the temperate zone. He can be caught in the same trap where he had been made prisoner only a few hours before. He does not fear man, with whom, it is true, he has but an imperfect acquaintance, which partially explains his freedom from timidity. On seeing a man, he retires to a little distance, stops, and scrutinizes the newcomer long before he finally takes his leave. He is easily domesticated, is not rancorous nor malicious, and is gentle and confiding. He is free from the odor of the fox. He is most cleanly, extremely careful of his person, and will not foul his lair.

Captain Lyon, who, in the eighteenth century, during two winters passed on Melville Peninsula, observed the arctic fox at close quarters, relates that when this fox is given anything to eat, his first impulse is to hide it as soon as he can, no matter how hungry he may be, even if he is alone and has no companions in captivity of whose probity he might be disposed to entertain some doubt. In such cases he makes great use of snow; for nothing is easier than to heap it up over the hidden store, and then to press it down hard with his nose. A captive fox often used an ingenious stratagem when he had no snow at his command. He would take the whole of his chain into his mouth, and then carefully wind it up on the ground so as to hide his meat. When he went away, satisfied with having accomplished his object, he would, of course, unwind his chain, and expose the meat. Thereupon, he would go at it again, as before, with the utmost patience, recommencing five or six times in succession, until, at last, tired of this business, he would make up his mind to swallow his prey without having rendered it more appetizing by keeping it underground.

The Eskimos take the arctic fox in ingenious traps which, according to Captain Parry, consist of a sort of little round hut of stone, closed everywhere except on top, where there is a square orifice. This orifice is closed by whalebone fixed only at one end, and passing across the aperture. A little snow put on the whalebone makes the place look like solid ground; but when the fox, attracted by bait so placed that to get it he has to pass over the whalebone, puts his weight upon it, it gives way, and down he goes, too deep to get out, while the whalebone springs back into place, all ready for another fox; and two are often caught.

The arctic fox, like many other animals, has a fur which varies much, both in abundance and in color, at different seasons. This fur, which covers even the plantar side of his paws, especially in winter (thus at once protecting them against the polar cold and facilitating locomotion over ice), is white in winter and in summer has a grayish-brown color, giving a slightly bluish effect. This transformation of the hair does not appear with other members of the dog family. Nor does it invariably take place; for there are arctic foxes that remain "blue" all the year round, while others never cease to be white. This led F. Cuvier to distinguish two species, the one changing color and the other remaining white. But, in fact, the two sorts of individuals belong to the same species; indeed, young of the two kinds may occur in the same litter, according to Schreber. On the other hand, it seems that in Iceland all the foxes retain their blue livery all the year round, never donning the white.

Even in his winter costume the arctic fox is never completely white, the nose and the end of the tail generally remaining black. Moreover, many foxes become rather gray than white during the dark season. Many are only relatively blue. This coloration presents numerous differences of [chromatic] intensity.

Seeing that the pelt of an arctic fox will sell for $20 or more, provided it be "blue," and for nothing at all if it be white, it is not to be wondered at that some ingenious spirits have been led to practice the breeding of these animals. The narrative of the Harriman expedition, recently returned from Alaska, informs us that the Alaska Commercial Company is doing this in several islands of the region it exploits, and in particular in the neighborhood of Kadiak, where the experiment has succeeded to perfection and where the company has established "blue-fox farms," which are in a flourishing condition.

These farms are, in fact, as simple as possible. The breeding simply consists in feeding the foxes during the winter, in protecting them from their natural enemies, and in only capturing and killing them under prescribed conditions. In order to be able to protect its wards, the company places them where they can not get away. It captures a number of them on the mainland and puts some couples on certain islands where there were none before and whence they can not escape. It provides for their needs by establishing stations on these islands where special employees go to carry the animals food, consisting mainly of fish, fresh or dried, or else put up in oil. No salt fish is given to them, because it is believed that that would mar the beauty of the fur. This food is left every day of the year in certain places, which the foxes get to know, so that they resort there.

Very ingeniously, the company causes the food to be always placed in traps, which, however, are not set too close. The animals thus acquire the habit of entering traps and do so without distrust. Thus, when it is desired to capture any, the traps are set and do their work with certainty. Food is given to the foxes all the year round, as much as they seem to need, judging by the haste with which they eat what they get. They get most in May, June, and July, because it is then that they litter, and the females consequently need a great deal of food.

When the fur is in fine condition the foxes are trapped in the manner above explained. The females are spared in order to favor multiplication, being set at liberty after having been marked with scissors in the caudal brush. Those males whose fur is suitable are killed; a few of the very finest are, however, set free to improve the breed.

It is to be remarked that the foxes do not live exclusively on the food furnished them. They eat, besides, what they find, which varies their fare, for they prowl about the shore and pick up any dead fish which the sea may throw up; they follow the bears and eat what they leave, and they hunt the rodents, so that in some of the farm islands mice have been quite exterminated. The best parts of the fish are not given to the foxes. They are fed on salmon mainly—the heads, and, in short, whatever is not dried or preserved for man.

It seems that not all the foxes are equally sensible of good and bad treatment from men. In most of the islands there are individuals who will not come to take the food that man distributes, but, avoiding the traps, live entirely on what they can find for themselves.

The foxes on the farms are numerous enough to be remarked as one goes about. Besides, they are curious and not timid. On an island of Prince William Straits there is a farm where 50 or 60 adults are fed on salmon and halibut. It is useless to offer them cod; they will not touch it. They are there accustomed to seek their food in a little house, which acts as a trap during the short period when their fur is the finest—that is to say, from December 20 to about January 10.

The arctic fox is abundant in the Pribylov Islands, or, rather, it was formerly so, and at present efforts are making to restore the abundance. On the island of St. George an American Government agent, Mr. Judge, has devoted several years to this question and has ascertained interesting facts. It is a rocky island, heaved up into a chaos, where birds flock in great numbers to breed, and is particularly suitable to the fox, if only his subsistence is insured for the winters, for otherwise he will not remain, but will embark on the first ice sheet which in spring comes near enough, and that will be the last of him, whether he reaches some distant shore or not. In summer he will remain quietly, for, in the first place, he can not do otherwise, and then birds are plenty, and eggs too, as well as young seals whose mothers have been killed and who have been left to starve. The pelagic hunting of the fur seal has been rather advantageous to the foxes because of the number of small seals which have perished and furnished food. There are some 2,000 foxes on the island of St. George. They fed upon lemmings (*Lemmus nigripes*) until the latter became well-nigh extinct. In winter they get their living on the shore, and, curiously enough, live largely on sea urchins, of a species of *Strongylocentrotus*, which are found on the rocks that are left uncovered at low tide. They also eat grass in winter, and worms, which they scratch out of the sand. They also swallow sea squirts and carcasses of fish. But, on the whole, their living is precarious at that season.

Attempts have been made, perhaps not persevering enough, to introduce rodents allied to the rabbit. The acclimatization of the spermophile found at Unalaska has also been proposed. Preserved food has been tried, such as linseed-meal biscuits. The foxes did not like it, though they take it eagerly when it is flavored with seal oil. Mr. Judge gave the foxes carcasses of seals, and these not being enough, he finally used entire bodies, salted or frozen, digging "silos," where the provisions were stored till they were needed. The foxes appreciated this kindness only too much, for one day 60 or 70 of them got into the silo, tore up and pulled out the seals, and feasted so that several of them died of surfeit. Since the foxes do not like salt meat, the seals are soaked in fresh water before being given to them. The seals are given to the foxes when the time of their capture approaches by every evening leaving some bodies, not more than ten, at the place where the traps are to be placed. At the proper time the traps are set. The females are set free, after having been marked, and some of them have been taken so often that their brushes have been quite spoiled. White females are, however, always killed in order to get rid of any tendency to the production of a breed that should turn white in winter and to establish a stable blue breed. The traps are large enough to take 40 foxes at once in each.

The practical problem of fox farms involves a psychological problem. In order to obtain the best results it is desirable that the foxes should practice polygamy. Now, they are naturally monogamous, but endeavors are made to induce them to become polygamous by reducing the number of males. The success of these efforts is still doubtful, but there are some encouraging indications. For example, the destruction of many males has had no appreciable effect upon the births. It may be noted that the collection of all the foxes into one place to feed makes promiscuous gatherings, which, it is hoped, may affect their moral nature.

According to the observations at St. George Island, the foxes have no predilection for any particular spot. They go about and only remain in one neighborhood as long as they are satisfied with the food. It is therefore easy to make them all come regularly to one place, and this is done. Their food is left near the village, and for the most part they remain thereabouts. It is easy to get sight both of the adults and the young, both of which are very curious about man and much given to observing him and his ways.

On this island, as elsewhere, it is stated that the arctic fox is much less astute than his European cousin. He allows himself to be taken in the same trap several times in succession, sometimes at intervals of ten minutes. Yet it will not fail to be remarked that neither this circumstance nor the fox's not avoiding places where man may be scented can seriously be regarded as a mark of low intelligence, seeing that the foxes who are so often trapped and let go again are thereby taught to regard the ambush as a joke. His experience assures him there is nothing to be feared. Those who are killed never return to tell the tale; and the arrangements are such that the others have no reason to suspect that any tragedy has taken place, for they are killed on a boat offshore, so that no blood may be spilled on the ground. Perhaps this is needless caution, for foxes are not very susceptible to extreme concern about deaths in their tribe, and they even resort to cannibalism whenever hunger presses them to it. So that the smell of blood or sight of remains of their kindred could hardly be very terrible to them; nor are their intellects so penetrating that they would be likely to draw inferences in regard to their own possible fate.

Observations at St. George Island show that the fur is in its perfection when the animal is in its first and second year.

The experience of farming is thus far encouraging. If success crowns the efforts that are making to break down the deplorable monogamy of the foxes, all will go well.

Some figures relative to the captures made in the season of 1898–99 may here be given. The "season," be it remembered, lasts but a few days, during which the animals' fur is in the exact state desired by the furriers and the public. During that season, then, 334 blue male foxes were taken and killed, 34 blue males were killed otherwise, 18 white foxes of both sexes were taken and killed, 110 blue males and 389 blue females were taken and set free.

DISCOVERIES IN MESOPOTAMIA.[1]

By Dr. Friedrich Delitzsch.

The traveler starting overland from the port of Alexandretta, in northern Syria, beholds beyond the high pass of Beilan the widely extended plain of Antioch, a view surprising in novelty and charm. As far as the eye can reach the plain is strewn with mounds of varying height, often grass covered, their artificial origin easily discernible. These mysterious elevations, called by the Arabs "Tell," by the Turks "Tepe," accompany the traveler to Aleppo and even farther to the banks of the Euphrates and Tigris, and they constantly increase in height, extent, and number, from Mosul down the stream and through Babylonia, crossing into the Elamite plain and to Susa. They are the marks of the civilization of pre-Christian millenniums. The large and small cities of the oldest empires of western Asia, of the Hittite states of northern Syria, of the Assyrian, Babylonian, and Elamite empires, with their palaces and temples, walls and gates, terraces and towers, lie buried beneath them. From these mounds of ruins of the Euphrates and Tigris region, weather beaten, grave, and silent, rising from the lonely and lifeless desert, French, English, and American explorers have plucked unfading laurels. They have awakened to new life, after the sleep of thousands of years, the buried glory of millenniums gone, and from innumerable monuments of sculpture and writing living knowledge reaches us of Babylon, Nineveh, and of those earlier peoples whose civilization continues, in not a small measure, to be preserved in our own. The mounds of ruins in the fairyland of "The Thousand and One Nights" have become for France, England, and America mounds of treasure-trove, from whose darkness they bring to light treasures of human art and science that are the greatest ornament and pride and the never-resting ambition of the great national museums.

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[1] Translation of Ex Oriente Lux. Ein Wort zur Förderung der Deutschen Orient-Gesellschaft von Dr. Friedrich Delitzsch, ord. Professor an der Universität zu Breslau. Leipzig: F. C. Hinrichs'sche Buchhandlung, 1898. pp. 16, 8vo. Dr. Delitzsch has also contributed other articles in this series of publications.

It was in the year 1820 that Claudius James Rich, an officer of the English East India Company at Bagdad, undertook, for the recovery of his health, a trip into the Kurdish Mountains, and on his way back he spent a few days at Mosul, the well-known commercial town on the right bank of the Tigris. There the large mounds on the other side of the river attracted his attention. They resembled those which he had seen near Hilla on the Euphrates and which he correctly took for the remains of ancient Babylon. As the southern of the two largest mounds still has the official name of Nunia, and is crowned with a mosque dedicated to the prophet Jonah, the hypothesis suggested itself that there, opposite Mosul, lay the ruins of Nineveh, the ancient capital of Assyria. Rich examined the mounds. He also heard of a large stone slab, engraved with representations of human figures and animals, which had been found some time before, but had been broken by the Turks because of religious prejudice. He was not, however, in a position to continue his investigations.

Now it happened that in 1842 Emil Botta, son of the well-known Italian historian, was appointed French consul at Mosul, and was encouraged by the famous orientalist, Julius von Mohl—the second of the four brothers Mohl, who are a lasting honor to their native city Stuttgart—to follow up the path entered upon by Rich and to begin excavations in the mounds near Mosul. But neither on the southern mound, Nebi Yunus, nor on the northern, Kuyunjik, were his endeavors rewarded with success. In March, 1843, a peasant of Khorsabad, a village situated four hours north of Mosul, told him that in the mound on which his village was built inscribed stones and similar objects had been found in great number. Botta thereupon began, on the 20th of March, to dig in Khorsabad, and after but three days a room was opened, and a few days later another, the inner walls covered with alabaster slabs, on which were represented in bas-relief the campaigns and hunts, the gods and priests of a king. Full of joy, Botta, on the 2d of May, sent to Mohl a letter, with drawings of the inscriptions and sculptures. The drawings caused a lively sensation, and the French Government immediately made an appropriation for further excavations. Botta had discovered, as we now know, the palace of Sargon, the conqueror of Samaria. In May, 1844, the inhabitants of the village were removed, with the permission of the Sublime Porte, and thereupon the excavations continued on a larger scale. New rooms were continually freed from the débris, new sculptures, still exhibiting traces of color, together with long-lined inscriptions, were continually brought to light, and the drawings of the French painter, Eugène Flandin, which were later published at the cost of the State, served to raise still higher the general interest in Assyrian art and civilization, which was believed irrevocably lost, and now, as if by magic, raised to new life. Botta's successor, Victor Place, found, in 1852, the walls and gates of the city of Sargon, with gigantic winged bulls, and completed the excavation of the palace, penetrating to the cellar, where the wine jars, with a reddish sediment in the bottom, were still standing in long rows. An Assyrian king, concerning whom until then only a simple brief notice in the Old Testament (Isaiah XX, 1) gave information, suddenly rose before our eyes as a live, tangible personage, and we now know as much about his wars and victories, his buildings and hunts, about the conditions of the civilization of the Assyrian Empire and the contemporaneous history of the neighboring states, as we know about any epoch of ancient Greece or Rome.

It may be readily imagined that the glorious achievements accomplished by French pluck, energy, and perseverance, which turned the eyes of the whole civilized world to the Assyrian collections in the Louvre, would not long leave the English idle spectators. Sir Austen Henry Layard, afterwards minister of Great Britain in Madrid and ambassador to Constantinople, had already visited those regions in 1840, and had shown the most lively interest in the work of Botta. It was not long before the English ambassador at Constantinople, Sir Stratford Canning, succeeded in securing for Layard the firman permitting excavations and the necessary funds. Layard immediately began excavations on a grand scale, receiving the cordial aid of the native population, for not only was Layard an adept in winning the love and gratitude of the natives everywhere, but he had also in Hormuzd Rassam the most ideal companion, who, fully familiar with the Arabic character, could, as Layard acknowledged, secure the good will of the most savage with whom he came in contact.

On November 28, 1845, Layard commenced his labors in Nimrud, situated a few kilometers south of Nineveh, and the first four months of 1846 brought to light the entire northwest palace of Shalmaneser I (1300 B. C.), the palace of Assurnazirpal, of the Biblical Tiglathpileser and Esarhaddon, and, especially with the palace of Assurnazirpal, a large number of sculptures and inscriptions of various kinds. Not less successful were the excavations at Nineveh, which Layard carried on after 1849 at the expense of the British Museum. Like the Babylonians, their masters, the Assyrian kings built their temples and palaces upon raised artificial terraces, from whose airy heights they not only enjoyed a purer and cooler atmosphere but escaped the fever, the inundations, and the mosquito swarms of the river flats. King Sennacherib erected such an elevated terrace of bricks, and his grandson, Assurbanipal, the Greek Sardanapalus, extended it. Both of these rulers built there magnificent palaces, surrounded by large parks, rivulets, and ponds, on whose isles water birds nested. And all this splendor and glory, covered by the mighty mound of ruins of Kuyunjik, were uncovered by the two English explorers. In the southwest corner of the mound Layard laid open the palace of Sennacherib, the largest Assyrian palace thus far known, with seventy-one rooms, galleries, and halls, the walls on every side covered with artistic bas-relief, depicting the edifices, the campaigns, and the domestic life of the king in a most vivid manner. There we see how the large terrace was filled up, how the gigantic bulls that guard the entrance to the hall were set in place by means of pulleys, rollers, and ropes, and a contingent of thousands of workmen, partly slaves in chains, whom the king superintended from his chariot, while pitiless taskmasters with raised sticks relentlessly urged on the work (Pl. IX). In another room the sculptures show servants carrying bunches of ripe dates and flat wicker baskets with pomegranates, apples, and grapes, grasping at the same time small green twigs to keep off the flies. They are followed by others with hares, partridges, and dried locusts fastened on staves. Farther on come servants, two abreast, carrying on their shoulders low tables loaded with baskets of cakes and fruits, while in the rear follow a long line of servants with flower-decorated vases. All these representations are distinguished by vividness and truthfulness.

Splendid and admirable as were the finds in the so-called southwest palace of Sennacherib, they were to be greatly surpassed by the treasures which were brought to light from the so-called north palace of Sardanapalus, discovered by Rassam in 1854. There, too, one state chamber after another was freed from débris; the long Babylonian gallery, the smaller Arabic room, so named because their wall reliefs represent the great deeds of the king and his armies in Babylonia, Arabia, etc. After two and a half thousands of years of darkness the light of the sun again burst in the halls decorated with sculptures and in the courts artistically plastered with mosaics, exactly as when they were deserted in the year 607 B. C., when the Median hordes, intoxicated with the blood of foes and the triumph of victory, raged there, burning and plundering. Light fell anew into the royal harem, conjuring up before our eyes most vividly scenes with which an artist of the seventh pre-Christian century decorated its walls with realistic truthfulness. We behold in an arbor the king comfortably stretched upon a divan holding a full goblet in his hand, and near him, likewise with a goblet, the queen on a high chair, attired in rich vestments. Eunuchs fan the royal couple, while at a distance there is music. Not far from these apartments the beautiful lions' room was found, its sculptured walls perpetuating the king's adventures in the chase. Like most of the Assyrian kings Sardanapalus was a bold, passionate hunter, and the lions' chase was his favorite sport. The lions were confined in cages in a special park and on the day of the hunt were set free. Here we see the king, now on foot, now in the chariot, taking up the battle with the lion. Now the king calmly meets the attacking animal, and, with a sure hand, thrusts the deadly spear into its body.

Assurnazirpal, King of Assyria 884-860 B. C.

Photograph from slab in the British Museum.

Assurbanipal, King of Assyria 668-626 B. C., and his Queen banqueting in the Garden.

Photograph from slab in the British Museum.

Assyrian Work. King A[illegible] B. C. [illegible]

[illegible]

There the furious beasts fasten their teeth in the chariot spokes or writhe wounded upon the ground. Especially to be noted is a relief of a dying lioness, whose perfectly realistic character has made it famous in the history of art. On the floor of the lion apartment and of the adjoining rooms lay in thick layers fragments of the royal library, a collection of tablet books and documents once arranged in the upper rooms, but which at the collapse fell through, crushed into thousands of large and small pieces. Baked clay tablets of all sizes, inscribed on both sides with fine Assyrian cuneiform characters, which, after being freed from dirt and dust can be as distinctly read as if they were but yesterday impressed into the soft clay, constituted this unique royal library.

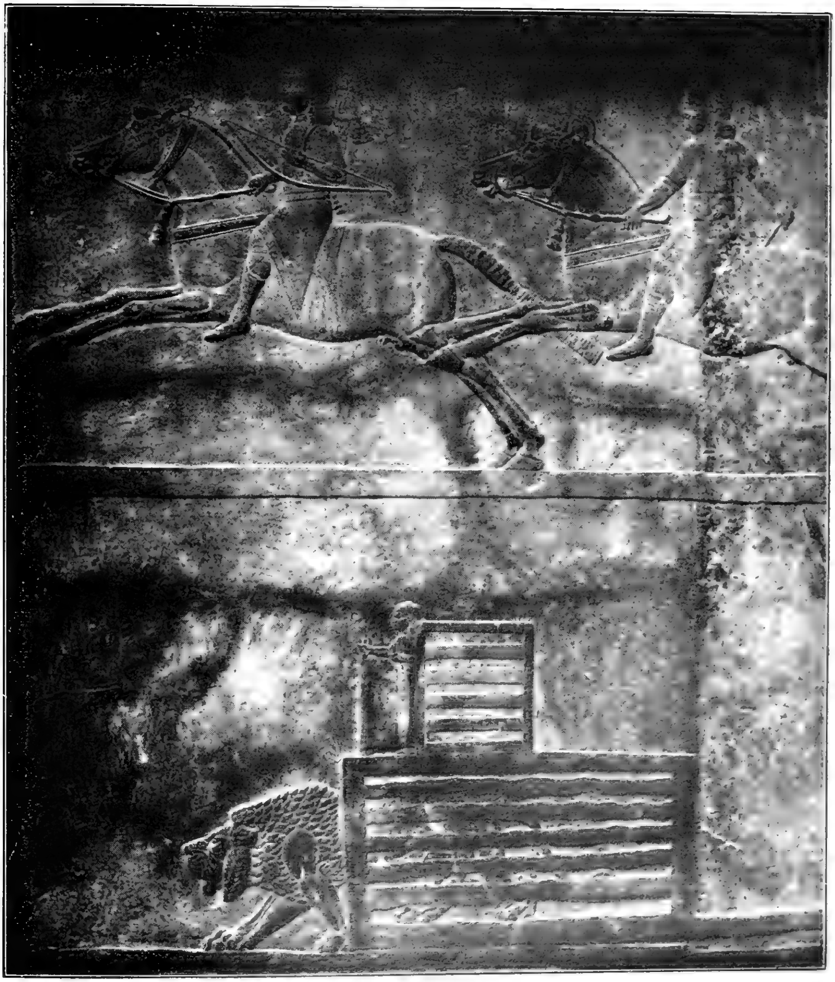
As if presaging the approaching collapse of the Assyrian Empire, Sardanapalus ordered that the most important books and documents from all the libraries in Babylonia should be collected, copied, some even in duplicate, and incorporated in his own library. Thus through the library of Sardanapalus there came to us a great part of the older, and indeed of the most ancient, works of Babylonian literature, and, as might be expected, only the most important works were considered worthy of admission into the royal library. It contained historical works with information as to the relations, now peaceful, more often warlike, of Assyria with its mother country, Babylonia; chronological lists accurately fixing the reigns of all those ancient kings, Shalmaneser, Tiglathpileser, Sardanapalus, and for a long period recording the most important event of each year; penitential psalms and hymns of praise, epics and myths that reveal the religious thought as well as the poetical endowment of the Babylonian people; large grammatico-lexicographical works that for many decades to come will be an inexhaustible mine for Semitic philology; astronomical, astrological, and magical tablets, the original works from which the wise men of the East—the Babylonian Magi—drew their learning which they afterwards spread over Greece and Rome; in addition a multitude of letters addressed to the great king of Assyria from the kings of Elam, from the generals abroad in hostile lands, from the court astronomers who report to the king the happenings in the starry heavens, eclipses of the sun and moon, from the Magi, who, on the basis of the flight of birds, or the entrails of sacrificial animals, advise the royal majesty what to do and what to leave undone; letters from the royal physicians, petitions and entreaties from captives; besides copies of the letters and proclamations of the king himself. Four royal-octavo volumes, with 1,952 pages, are required for the catalogue of the thousands of clay tablets and prisms or fragments thus far transferred from Nineveh to the British Museum. And what a mass of knowledge and multitude of new points of view for religious and profane history, for linguistics and geography, for archæology in all its branches, has not the study of these ancient books revealed! Let us but recall that memorable autumn of 1872, when George Smith, one of the officers of the Egypto-Assyrian collection of the British Museum, while looking over the cuneiform fragments of the mythological series, read in one of them with growing surprise: "The ship stood still on the Mount Nizir. I took out a dove and sent it out; the dove flew hither and thither, but as it found no resting place it turned and came back. I took out a swallow and sent it out. The swallow flew hither and thither, but as there was no resting place it came back. I took out a raven and sent it out; the raven flew away and perceived the decrease of the water * * * and did not return to the ship." Smith had found the original of the Babylonian-Biblical account of the deluge. He reported his find at the meeting of the London Society for Biblical Archæology on December 3, 1872. The discovery created the profoundest sensation in England, and far beyond her borders. In press and pulpit it was celebrated and commented upon. Babel, it was said, confirms the Bible. "Where men are silent, the stones cry out." The proprietors of the Daily Telegraph, almost immediately after that lecture, hastened to give George Smith a thousand guineas for further explorations in Nineveh. On January 20, 1873, George Smith set out on his journey. In 1874 he was again sent—this time by the trustees of the British Museum—to Nineveh, constantly making discoveries, and in 1876 undertook a third expedition to the East, which was to be for him "a way without return." His last stay in Babylonia and Assyria—full of exertions and trials, where, at the time, pest and cholera were raging—exhausted the strength of the indefatigable explorer. Accompanied by the English consul to Aleppo, he died there on August 19, 1876, covered with glory, fallen like a hero on the field of honor.

The traveler setting out from Bagdad in the direction of the little town of Hilla, traversing the plain which is spread out between the twin rivers Euphrates and Tigris where they are nearest one another, will, after passing many other mounds of ruins, arrive at a large one covering 2 English miles, named Abu Habba. Wall and castle are still clearly recognizable, but the highest point of this site of ruins is on the southwest side on the bank of a former arm of the Euphrates. When Rassam excavated here in 1881 he struck almost at once the walls of a building. The inclosure of a large quadrangular structure, 1,500 feet long on the southwest side, was laid bare, and further trenches and shafts showed that the edifices were grouped around a central court, and consisted of a line of long narrow rooms with exceptionally thick brick walls. In the interior of this structure a pair of interesting rooms was discovered and freed from the débris. At the excavating of a shaft that ran along a wall in the middle of the mound a doorway was reached which led to a large gallery 100 feet long and about 35 feet wide. On it stood the remnants of a large sacrifical altar, made of bricks and measuring 30 feet square. Behind the altar, in the wall of this room, a door opened leading to a smaller room, and Rassam, as a result of experience gained in the Assyrian mound of Balawat, at once surmised that the temple archives had been here preserved. But though at Balawat the corner-stone documents of the builder of the temple were found in a stone chest, nothing similar was here discovered. On the other hand, the asphalt pavement attracted Rassam's attention, and he therefore sunk a shaft in the floor, when, behold, scarcely had he broken through the cement layer when a clay chest appeared containing a beautiful artistically inscribed alabaster tablet, in six columns, decorated at the top with a carefully executed bas-relief. In this holy of holies a god with a long-flowing beard, in his hand a ring and short staff, was seated upon a throne decorated with cherubim. A king followed by two priests approaches the god in adoration, while two other men are raising the sun disk with ropes upon the roof of the holy of holies. Certainly a valuable and admirable find in itself, but much more so because this document also revealed the name of the building and of the city which was thus rediscovered. "Image of the sun god, the great lord, who dwells in the temple Ebabbara in the city of Sippar." Thus reads the explanatory legend of the bas-relief. One of the oldest Babylonian cities has been found—Sippar, in which Noah-Xisuthros, by the command of the god Kronos, was ordered to bury the documents of antediluvian times; the sun temple, which since its foundation in the fourth millennium until long after the time of the last Chaldean king, Nabonaid (538 B. C.), was the center of worship for Babylonia and the object of concern of all Babylonian kings, was rediscovered. This sun temple in the course of thousands of years, through revenues and donations, came in possession of untold riches in money and land.

The forty to fifty thousand inscribed tablets that since 1881 have been flowing from Abu Habba as from an inexhaustible source into the occidental museums, above all into the British Museum, give an insight not only into the cult of the sun god and the deities worshiped beside him, into the division, obligations, and prerogatives of the several priest classes, but also into the system of the temple revenues and their application. From the temple archives of the sun god is derived a great mass of tablets, which, after the fashion of commercial bookkeeping, record the temple revenues in money and other commodities, the expenses in salaries, wages, etc., and the investment and employment of the temple property in loans, real estate, rents, etc. If to these be added the numerous so-called contract tablets from Babylonia, Tell Sifr, and other places, with their varied contents, purchase and sale of slaves, marriage documents, acts of lawsuits, testaments, and the letters of the time of Hammurabi or Amraphel

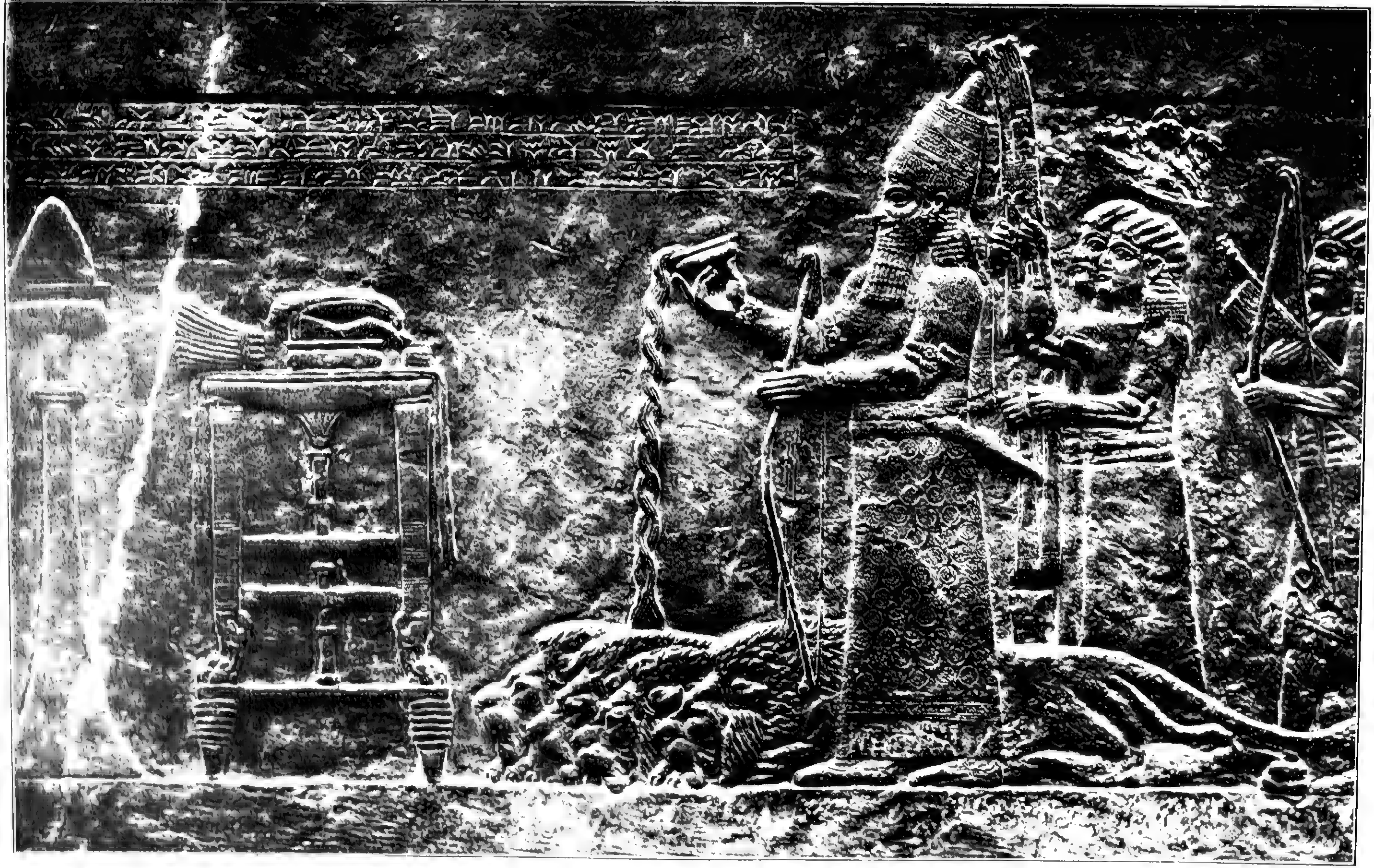
(Genesis, xiv) which were recently found, we derive a mass of the most important information on the commercial and judicial life as well as the economic conditions in the Babylonian State for a period of nearly two thousand years from the first Babylonian dynasty (2250 B. C.) until long after the time of the Achæmenian kings. The excavations at Sippar, Babylon, and elsewhere carried us back to the time of Hammurabi, that greatest king of the first Babylonian dynasty, who united the north and the south in one great Babylonian State, with Babylon as the capital. But the soil of Babylonia, inexhaustible in surprises, was soon to afford us an outlook into a much higher antiquity of the Babylonian people and to carry us to still more remote ages in the history of humanity. From the same archives to which the above-mentioned votive tablet belonged, which was deposited by King Nebobaladan (882 B. C.) in the sun temple at Sippar, came also, among other things, a remarkable clay cylinder of the last Chaldean king, Nabonaid. In it the king relates that he has decided to reestablish the sun temple upon its oldest foundation; for, in consequence of the repeated rebuildings in the course of many centuries, the temple was obviously detached from its original foundation site, from its oldest "temen;" and that he has succeeded, after continuous and laborious digging into the depths of the earth, in finding the "temen" of the first builder of the temple Naram-Sin, son of Sargon I, a "temen" which for thirty-two hundred years had not been seen by the eye of man. This established the year 3750 before our era as the date of the reign of Naram-Sin and about 3800 as that of Sargon I, and opened a vista into the past of the human race on Babylonian soil which lies fifteen hundred years beyond the time of Hammurabi-Amraphel, or, to speak with the Old Testament, beyond the time of Abraham, a vista never anticipated and at first hardly credible. And still, little as was the inclination to accept so remote a date, there was as little reason to doubt it, and, in fact, the progress of the excavations was soon to prove it more and more indubitable.

The French consul at Bassora, Ernest de Sarzec, who has been directing the French excavations on the south Babylonian site of the ruins of Tell Loh (Telloh) since 1875, had not long begun his work when he found those nine diorite statues, which represented partly in standing position, partly seated, the old priest kings (patesi) of the city of Lagash, named Ur-Bau and Gudea (Pl. X). These statues, although the heads of all are missing, are valuable examples of the old Babylonian art of sculpture, and this value is considerably increased by the inscriptions which, on the breast, back, etc., are incised with the most consummate artistic skill and neatness, exciting the admiration of our modern stonecutters. While the archaism of the writing leads us back to a time long before Hammurabi, the language in which they are composed shows that those ancient priest kings belonged neither to the



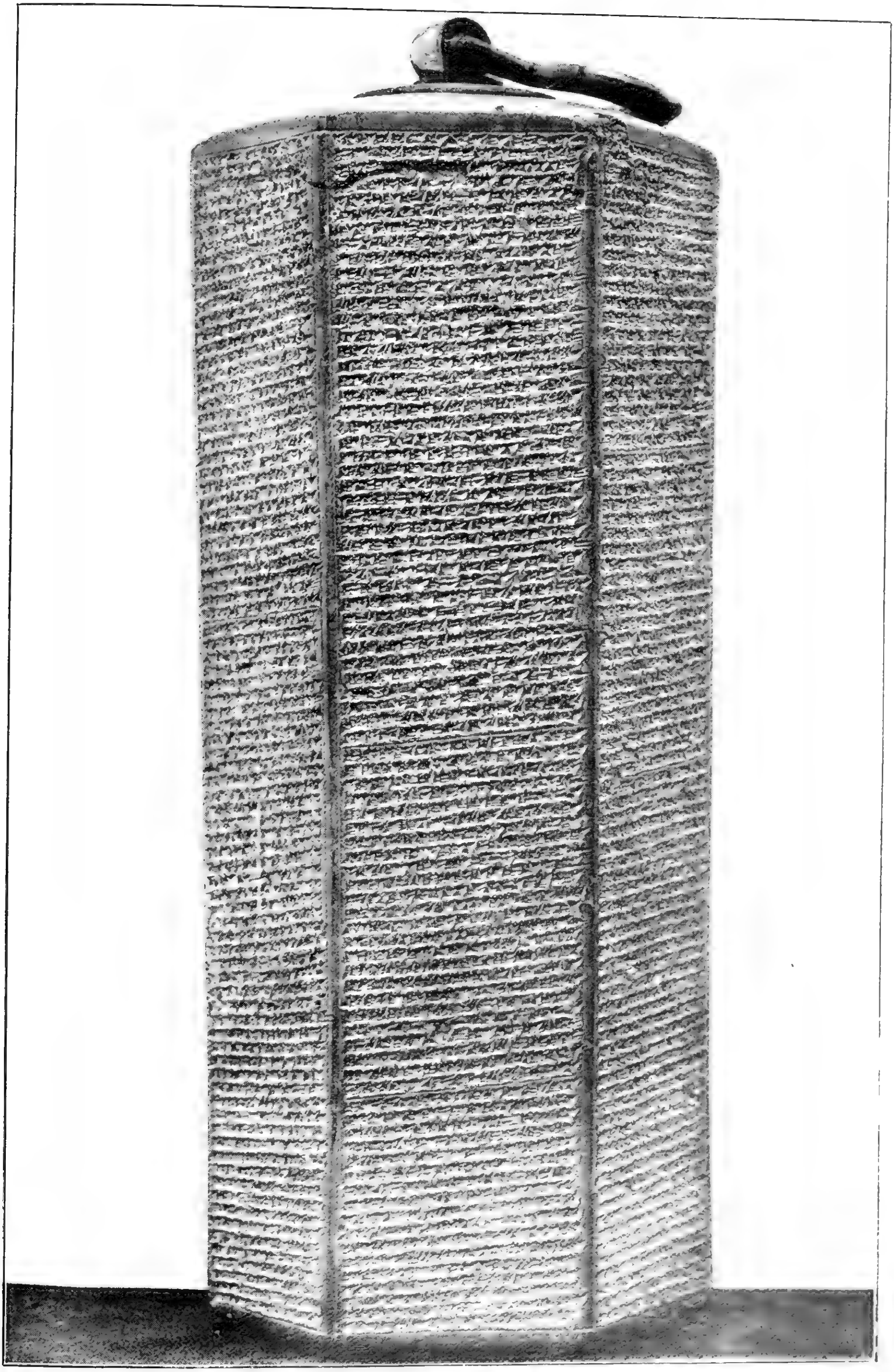
CAPTIVE LIONS RELEASED FROM CAGE FOR THE ROYAL SPORT.

Photograph from slab in the British Museum.



ASSURBANIPAL POURING A LIBATION OVER LIONS SLAIN IN THE CHASE

Photograph [illegible] in the British Museum



ASSYRIAN ACCOUNT OF SENNACHERIB'S CAMPAIGN AGAINST JERUSALEM AND KING HEZEKIAH OF JUDAH (701 B. C.).

Photograph from terra-cotta prism in the British Museum.

Semitic nor to the Indo-Germanic stratum of the Babylonian population, but to the so-called Sumerian people, who spoke an agglutinative language, and who, though through the early centuries settled in Babylonia contemporaneously with the Semites, and in lively intercourse with them, must still be considered as the older native population from whom the Semites received the art of writing and other achievements of civilization. And since that first great discovery of De Sarzec, the finds of Telloh have steadily carried Babylonian history to earlier periods, as is evinced by indisputable art, historical and paleographical criteria. They carried it back to the time when the two Semitic kings of Agade, Sargani-shar-ali and Naram-Sin—and these, as is recognized with ever-increasing certainty, are Nabonaid's Sargon and Naram-Sin (3800 and 3750 B. C., respectively)—exercised sovereignty over Lagash, and the priest king of this city, Lagal-Ushumgal, was their vassal. Nay, even from an earlier time—the close of the fifth milleninum—there rises before our eyes a whole line of hoary Sumerian patesis of Lagash—Ur-Nina, Akurgal, Eannadu, Enannatum, Entemena. And we know not only their names but most of their heroism against domestic and foreign foes, and of their efforts for the general welfare of their city and its inhabitants.

As the origin of the cuneiform writing is more and more cleared up through the inscriptions of some of these most ancient rulers—above all, that of Eannadu—so one ray of light after another brightens the darkness spread over the earliest history of the great Babylonian cities—Agade, Babel, Kish, and Lagash, Erek, and the "city of bows." Nay, on some periods, especially the times of Sargon I and his son, Naram-Sin, a flood of light is shed. For much as it may be deplored that the archives, consisting of some 30,000 tablets, cylinders, and large inscribed pebbles, found in 1894 in a cellar-shaped room at Telloh, were scattered everywhere by the thievish Arabs, the documents themselves are not lost to science, whether they came to the museums of Constantinople, Paris, Berlin, Philadelphia, or elsewhere, and they reveal to us in a surprising and at the same time in detailed manner the commercial, agricultural, and economic conditions, as well as the civic and religious life of the times of Sargon I and Naram-Sin. Even pierced lumps of clay were found with the names of Sargon or Naram-Sin stamped upon them, inscribed with the names of the addressee, the place of destination, and evidently attached to bales of merchandise, to be forwarded from Agade to Lagash.

One of the oldest sanctuaries upon earth is the temple of the lord of the universe, Bel, in the middle Babylonian city of Nippur. The ruins of this city, now called Nuffar, and especially the gigantic remains of this temple, were the goal of the three expeditions from Philadelphia, which, from 1886 up to the present time, under the direction of John P. Peters, Hermann V. Hilprecht, and J. H. Haynes, have excavated and constantly made discoveries of the greatest import to science on that vast site of ruins. Two temple archives rewarded the labors of the American explorers within a few years. True, those of Sargon I lay in ruins; enemies, probably the Elamites, plundered and destroyed them. But if only the vases of the pre-Sargonic king of Erek, Lugal Zaggisi, son of a patesi of the "city of bows," which were pieced together from thousands of fragments, had been found they would be an ample reward on account of the historical and paleographical information that they furnish. The records of the Kossean kings were intact. They contained all the votive gifts that the kings of the so-called third Babylonian dynasty had presented to the god Bel.

Down to 1896 there were cleared from the ruins of Nuffar, successively, 2,000, 8,000, and 21,000 clay tablets and fragments, inscribed and stamped bricks, stone and clay vases. They were of the pre-Sargonic period, as well as of all the later periods of Babylonian history, from Sargon I and Naram-Sin, and even from Ur-Gur and Dungi, the two ancient kings of the city of Ur, down to Darius II and Artaxerxes Mnemon. They embraced syllabaries, chronological lists, letters, astronomical and religious texts, tax lists, plans of real estate, contracts, besides images of divinities and toys of terra cotta, weapons and implements of stone and metal, ornaments of gold, silver, copper, and bronze, carved precious stones and weights. It was estimated that the inscribed monuments found up to 1896 would fill 12 volumes of two to three parts each if published. What specially distinguishes the excavations of the Americans is the systematic clearing up of the single layers of the mighty temple edifice and of its superstructure.

The colossal ruins of the tower of the temple of Bel, now called Bint-el-Amir, rises 29 meters above the plain and 15 meters above the mass of débris which surrounds it. The immense platform, about 2.40 meters thick, constructed of sun-dried bricks, together with the three-story temple tower erected upon it, probably a work of King Ur-Gur, was laid bare and the ascent to the single stages in the southeast of the ruin was found. Close under this platform another pavement was discovered, consisting of two layers of baked bricks of about 50 centimeters square and 8 centimeters thick. Most of them were stamped, some with the name of Sargani-shar-ali, the others with that of Naram-Sin. Both kinds were intermingled in both brick layers, so that the identity of Sargani-shar-ali with the Sargon of Nabonaid (3800 B. C.) was made sure. Ur-Gur had, it appears, razed the buildings of his predecessors and elevated the platform of his temple tower over the pavement of Naram-Sin. J. H. Haynes, however, who since 1894 has been alone at the ruins of the temple of Bel, superintending the excavations, was not content with these chronologically important revelations, but sunk shafts in several places under

Naram-Sin's platform and searched the entire earth stratum, which was about 9.25 meters deep, down to the underground water, for remains of human civilization. This great sacrifice of time, labor, and perseverance was to be rewarded in a way that could not have been anticipated. For, in one place, not far below Naram-Sin's platform, was found an altar of sun-dried bricks, the top of which was surrounded by a rim of asphalt and covered with a layer of white ashes 6.5 centimeters thick and the remains of burnt sacrificial animals; still farther below there was unearthed a large, beautifully decorated terra-cotta vase in perfect condition, an excellent example of old Babylonian ceramic art. And in another part of these underground excavations the oldest architectural arch of a drainage canal, and still farther down, in the deepest layers, or, what amounts to the same, back in many centuries beyond the fifth millennium, everywhere interesting and valuable remains of human civilization came to light, fragments of vessels of copper, bronze, and clay, a mass of earthenware, so beautifully lacquered in red and black that one might consider them of Greek origin, or at least influenced by Greek art, had they not been found 8 meters deep under Naram-Sin's pavement.

We could go on a long time in this way were we to enumerate all the achievements which foreign explorers, supported by the energetic interest of their governments and aided by the liberality of their countrymen, have accomplished and are still accomplishing on the ruined sites of Assyria, Babylonia, and Elam. We could speak of Hormuzd Rassam's finding of Nebuchadnezzar's palace in the middle mound of Babylon, called Kasr; of two beautiful wells which reached down to the water level of the Euphrates, and of other traces of water balances in the extreme northern mound Babil, probably the site of the hanging gardens of Semiramis. We could describe the successful expeditions of Jules Oppert, William Bennett Loftus, Sir Henry Rawlinson, and, above all, tell of the great work of the Dieulafoys on the ruins of Susa. But we must forego this here, and will mention in passing that only recently the French Government succeeded in acquiring for 5,000 francs the right from the Shah of Persia to excavate for all time in Susa and the surrounding province and to transfer half of the finds to France, while for the other half it secured the first option. The French have been active in Susa since November, 1897, under the direction of De Morgan. De Sarzec and Haynes continue their labors with undiminished and untiring zeal. Philadelphia, it is rumored, is equipping a new expedition, and Germany—is she to continue for another half century to be an idle and admiring onlooker of the glorious deeds of foreign nations? Shall she longer be content to play the part of the poet, until it is proclaimed: Too late; the world is already divided?

Germany may justly be proud that one of her sons, the Hannoverian Georg Friedrich Grotefend (born in 1775 at Münden), as a young teacher at the gymnasium of Göttingen in 1802, had the genius to decipher the cuneiform writing, and thus placed the key in the hand of science which was to unlock not only the old Persian monuments but also the great Babylonian-Assyrian cuneiform literature, and in addition to that make possible the reading of the Armenian and Elamite cuneiform script. Germany may also glory in the fact that a scholar of German blood, Julius von Mohl, gave the first impulse to the excavations in Nineveh; she can also note with satisfaction that the enthusiastic interest which is being brought to the Assyriological studies, especially in America, and from which grew the Philadelphia expeditions, was awakened in the German universities. If, then, Germany would at last arouse herself and secure a share of the priceless art and written monuments of the old—nay, oldest—human civilization for German museums and German science, this great national and scientific undertaking may count with certainty upon the sympathy and self-sacrificing support of all men and women who are zealous for the glory of the German name and German science. No one can deny that the excavations in the mounds of Mesopotamia have opened and are continually opening new and rich sources of highest importance for an entire series of sciences—Old Testament research, ancient history and geography, the history of art and archæology, the history of religion and comparative mythology, Semitic and general philology, comparative history of jurisprudence, the history of astronomy and mathematics, and many other sciences. We must refrain from entering into details and can only briefly refer to a few facts.

For the history of art, particularly the history of sculpture and architecture, and in a measure also of painting and some of the industries, such as stonecutting and pottery, a peculiar and highly important link was recovered through the resurrection of Assyro-Babylonian antiquity, the more important as the history of the development of the Babylonian art can be followed up to the fifth pre-Christian millennium. The image of Naram-Sin found at Diarbekr, the famous vulture stele of Eannadu, the sculpture with the representation of Ur-Nina and his sons, will forever remain milestones in the history of the art of western Asia, and of human artistic skill in general. And as it is an established fact that "the forms of the column, and some other ornaments of Greek art which are much in use, are first met in Assyrian sculptures," light from the East may also be hoped for to illumine the darkness in which the origin of the oldest Greek art is in many respects still enveloped.

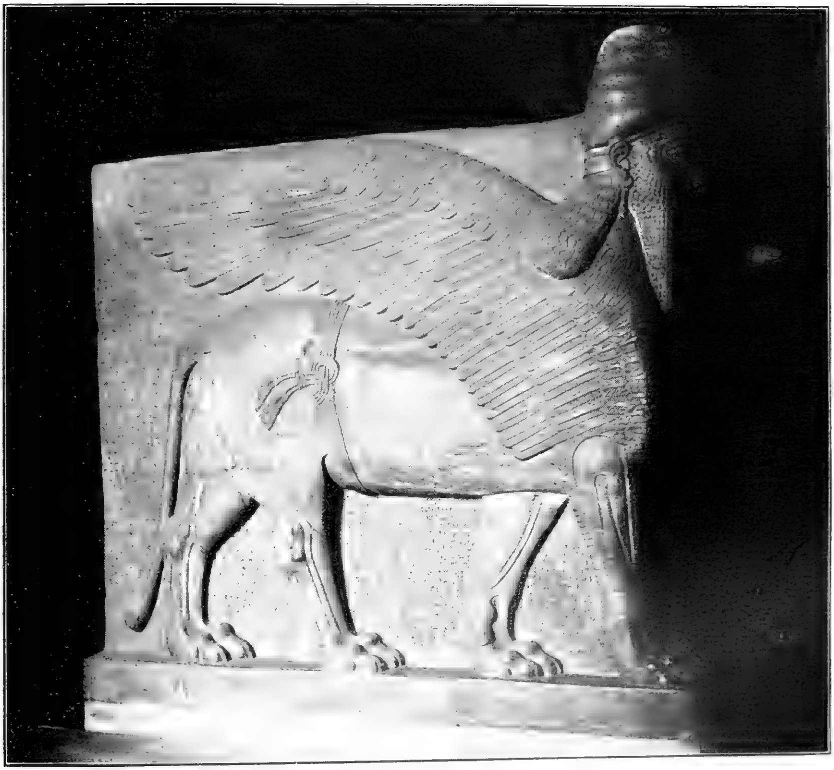
The light which sprang from oriental ruined mounds has with one stroke illuminated the sphere of the ancient peoples and States of western Asia, so distant in time and space, and restored it to ancient history. The nebulous forms of Ninus, Semiramis, and the effeminate Sardanapalus have been replaced by clear-cut individualities. The old great culture States—the old Babylonian, Assyrian, and Chaldean empires, their external political history and internal development in commerce and industry, law and religion, manners and customs—enter into our horizon with steadily increasing completeness and vividness. At the same time they furnish us the most valuable information on the history of the neighboring kingdoms, from Elam to Canaan, on the ethnic movements which during four millenniums took place in the large quadrangle of lands between the Black and Caspian seas and the borders of Egypt-Arabia. And how many chronological and geographical riddles have not been solved or at least brought nearer to solution!

Assyriological research which sprung from the ruins of Babylon and Nineveh has above all shown itself fruitful for the science of the Old Testament, and for it promises to bear still more fruit. For not only is the Assyrian language most akin to Hebrew, affording new information on questions of grammar, lexicography, and phraseology, but there is scarcely a book of the Old Testament the interpretation of whose subject-matter has not been aided to some extent by the cuneiform monuments. The narratives and conceptions of the Book of Genesis of the creation of the world—the serpent as the arch enemy of the Deity and embodiment of all sin and malice, the ten patriarchs, and the catastrophe of the Deluge which destroyed primitive humanity, so well known and familiar to us from childhood—appear in a new light through the surprising parallels which the Babylonian-Assyrian clay books furnish. The Old Testament history, especially that of Israel from Chedorlaomer to Belshazzar and the Achaemenian kings, interlinked with the history of Babel and Asshur, continually receives new light from the latter. The chronology of the kings of Judah and Israel is, through the chronology of the Assyrian empire, placed on a more secure basis than was possible before; and since in the annals of the Assyrian kings mention is made of the kings Ahab and Jehu, Pekah and Hosea, Ahaz and Hezekiah, the possibility is afforded of comparing more than one narrative of the historical and prophetical books, as, for instance, that of Sennacherib's campaign against Jerusalem, with the records of the opposing side. Hebrew antiquity is connected by hundreds of threads with that of western Asia, particularly of Babylonia and Assyria. The deeper insight which we now have into the belief and cult of the gods, especially into the nature of the sacrifices of the Babylonians, their conception of the winged angelic beings after the manner of the cherubim and seraphim, their views of life after death, their bestowing of names, the peculiarities of their psalm poetry in form and matter, their manners and customs, their system of measures and weights, etc., directly serve the advancement of Old Testament theology and archæology.

The resplendence of the starry sky over the endless expanse of the Euphrates' land is something wonderful; the stars sparkle with the greatest brilliancy, and the movements of the planets, the changes of the moon, the various meteors, enchant the attention at night. The Babylonians learned to calculate the course of the stars; their observations constituted the foundations of the astronomical studies of the learned Alexandrians. And when we even to-day divide the circle into 360 degrees, the day into twelve hours of sixty minutes; when we count seven days of the week and name them after the planets; when we divide the apparent path of the sun according to the signs of the zodiac, we therein directly follow those old Chaldeans, whose great scientific accuracy, while it has left traces in some other things, has borne imperishable fruit in the science of astronomy, which originated with them. And just as the first chapters of the history of astronomy can only be written with the aid of cuneiform works or notices, we must see in the same sources the history of mathematics, geometry, metrology. Nay, in many respects our present civilization is still under the influence of the hoary Babylonian; the week and its seven days and the names of so many constellations, as well as our old square measure, the cubit, and our old weight, the pound, have their homes in Babylonia. Jurisprudence has good reason for the assumption that the often striking agreements between Roman and Babylonian law will clear up the origins of Roman law, which, at least partly, are still obscure. In the exceedingly rich Babylonian-Assyrian "contract literature" an abundant as well as a valuable source was disclosed for the comparative history of jurisprudence; many other functions of state institutions receive new and instructive data of a comparative and historical nature from the results of the excavations. We have in mind, for instance, the economic development of those ancient culture states, or of the history of war in its manifold branches. Do not the bas-reliefs on the alabaster slabs and bronzes of the Assyrian palaces furnish instructive information as to the progress in the clothing and arming of the Assyrian army, the developing of the cavalry, the technique of fortification, the defense and attack by means of machines of assault and mines, on scouting and pontoon building?

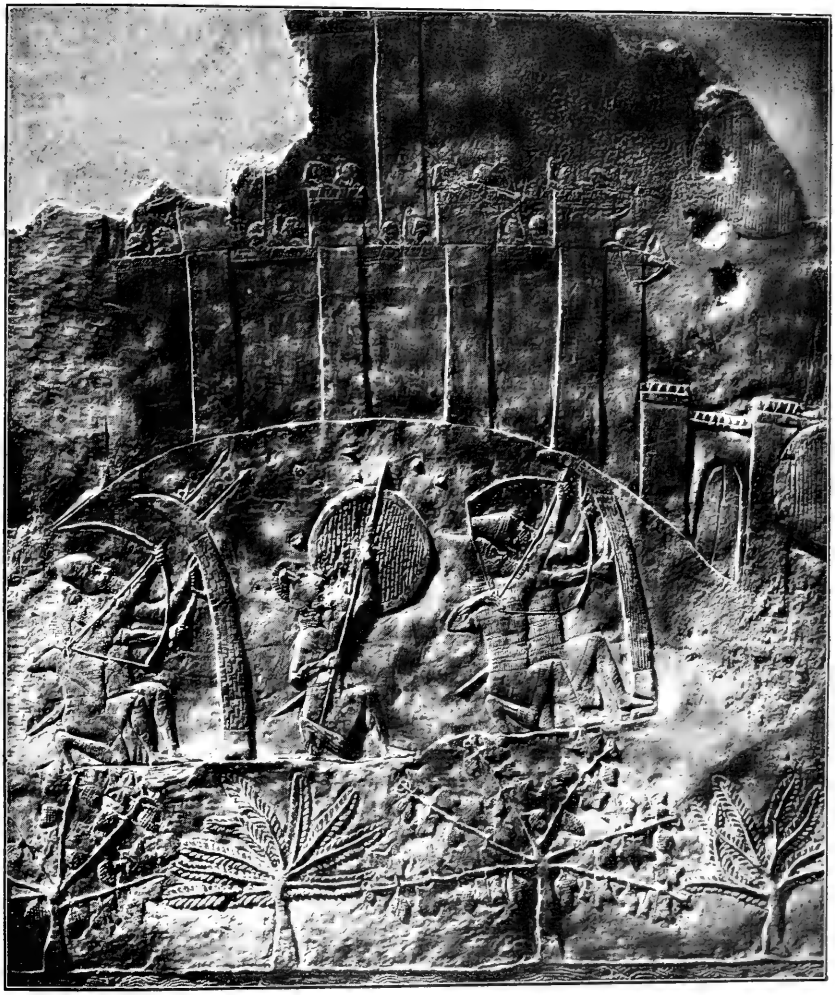
A new world is opened to human knowledge and inquiry through the Babylonian-Assyrian excavations. But while we zealously collect books and documents in our libraries and archives as the obvious condition of scientific progress, we stand idly by when the oldest documents and books and art monuments of humanity, the invaluable original material for a large number of scientific departments, go abroad, so that German Assyriologists, Old Testament scholars, historians, all who occupy themselves with the archæology of western Asia, with the history of art, etc., are almost entirely dependent upon foreign publications and foreign museums.

But still another consideration peremptorily demands that a change of conditions should as soon as possible take place. We German scholars continue to praise the ever-extended welcome which we receive from the directors and assistants of the British Museum, the Louvre, the National Library at Paris. We have to acknowledge the generosity with which the foreign collections are opened to us, the museum publications presented to us as a gift. But the more often we enjoy English and French hospitality the more urgent becomes the reminder, noblesse oblige. For more than fifty years German science has been availing itself of the fruits of foreign labor and sacrifice, and has been making use of achievements possible not only through enormous expenditures of money, but also by continuous sacrifices of time and comfort, health and life, on the part of the foreign explorers. It is not a small thing to do excavating yonder in Babylonia, in a climate whose temperature reaches in the shade 39° Réaumur (119° F.), among wild, ignorant, and treacherous Arabs, in the vicinity of widely stretching swamps, full of deadly fever germs, attacked by day and by night by ubiquitous insects. If the explorers of other nations are constantly ready to endure such sacrifices of health, nay, even life (the cemeteries of Bagdad and Aleppo bear witness to it), to science, it is certainly high time that Germany, too, imbued with a similar lofty national and scientific enthusiasm and readiness of self-sacrifice, put her hand to the raising of those treasures which are most valued by herself. There is certainly no lack of men who are ready for any sacrifice in the service of the fatherland and of science. As for the money, all Germany will certainly be able to do what a few generous citizens of a single American city, Philadelphia, have accomplished, they having defrayed the expenses of three expeditions from 1888 to 1896, amounting to 280,000 marks ($70,000). The self-sacrifice of generous Germans, which from 1888 to 1891 rendered possible the successful excavations of the German Orient committee at the mound of ruins in Sendjirli, in northern Syria, will certainly not be wanting for researches on the Babylonian-Assyrian ruined sites, which, in all human probability, will be much more successful, and will put the newly organized German Orient Society in a position to energetically carry out from now on uninterruptedly and in a constantly widening compass its efforts for the study of western Asiatic as well as Egyptian antiquity for the prosperity of German museums and German science and for the glory and honor of the German fatherland.



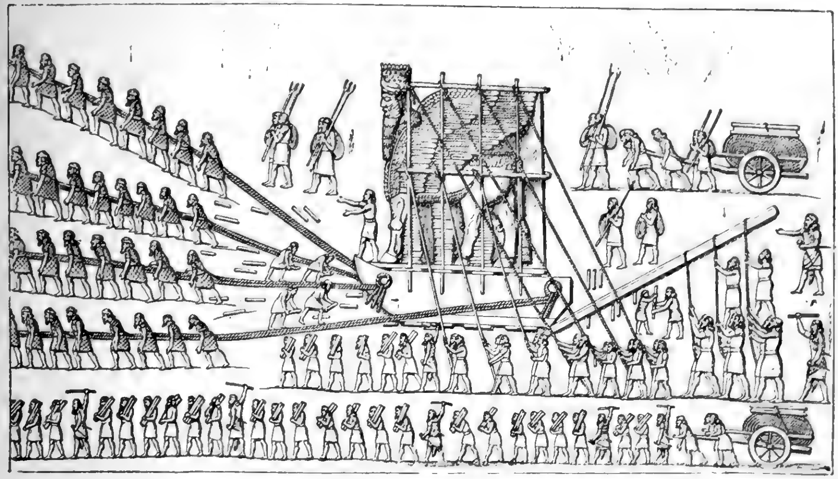
ASSYRIAN CHERUBIC FIGURE: WINGED HUMAN-HEADED LION.

Photograph from original in the British Museum



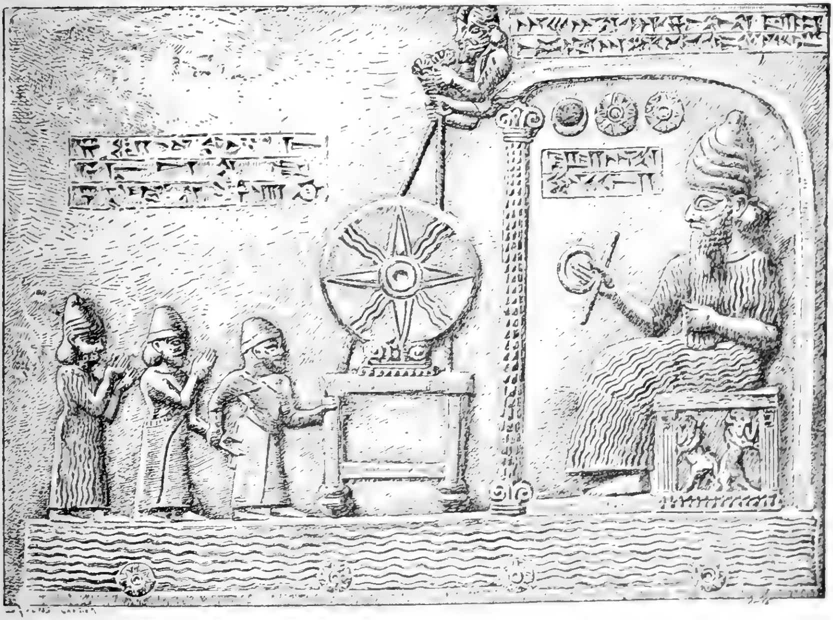
ASSYRIAN ASSAULT OF A CITY (CAMPAIGN OF SENNACHERIB, KING OF ASSYRIA 705-681 B. C.).

Photograph from original slab in the British Museum.



TRANSPORTATION OF COLOSSAL WINGED BULL.

From the book of Psalms, page 172, in the Polychrome edition of the Bible, by courtesy of Prof. Paul Haupt.

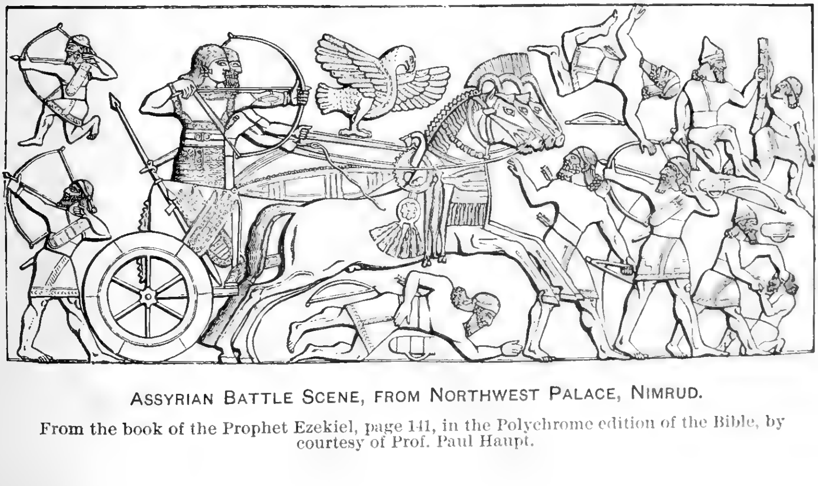


TABLET FROM THE TEMPLE OF THE SUN GOD OF SIPPARA.

From the book of the Prophet Isaiah, in the Polychrome edition of the Bible, by courtesy of Prof. Paul Haupt.

STATUE OF GUDEA.

From the book of the Prophet Ezekiel, page 171, in the Polychrome edition of the Bible, by courtesy of Prof. Paul Haupt.



ASSYRIAN BATTLE SCENE, FROM NORTHWEST PALACE, NIMRUD.

From the book of the Prophet Ezekiel, page 141, in the Polychrome edition of the Bible, by courtesy of Prof. Paul Haupt.

ON ANCIENT DESEMERS OR STEELYARDS.[1]

By Herrmann Sökeland.

The Anthropological Society of Berlin has occasionally received descriptions and seen exhibitions of simple weighing instruments which were called, in German, desen, desemer, besemer, or besen. A discussion in the Folklore Society of Berlin resulted in deciding in favor of the form "desemer."[2]

I was thus led to inquire what was known about such balances. Two ways suggested themselves for prosecuting this inquiry by testimonies and by monuments; that is to say, by reading what is recorded on the subject in books, and by directly comparing German desemers with more or less similar instruments of other peoples and ages which are to be found among the treasures of the different museums of Berlin.

Though there are many sterling works upon the construction of every conceivable description of balance, and an extensive literature of weights and measures, yet I have succeeded in finding nothing worth mention concerning the development of that which might well be suspected to have been the first device for weighing—the desemer. So crude a contrivance could have no interest for the artificer. Besides, the simple but imperfect instrument which is called in north Germany a desemer has become almost unknown to the present generation, and the consequence has been an increasingly frequent confusion between the desemer and the Roman steelyard. What we mean by a desemer, or, as it is called in the Altmark, an Uenzel, is something like a steelyard of wood or metal having its counterpoise fixedly attached to it, while the piece upon which it rests and turns can be shifted. The Roman balance, or what is usually understood by a steelyard, the German Pfünder, has, on the other hand, a fixed fulcrum and movable

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[1] Translated from Verhandlungen der Berliner Gesellschaft für Ethnologie, etc., Berlin, 1900.

[2] It has been assumed that this word is the same as "besen," the English form of which is "besom." The "steelyard" is so called because it was first used on the left bank of the Thames, at a place where the Hanse merchants sold steel. It seems quite possible that the original form of the balance used there was the desemer.—Tr.

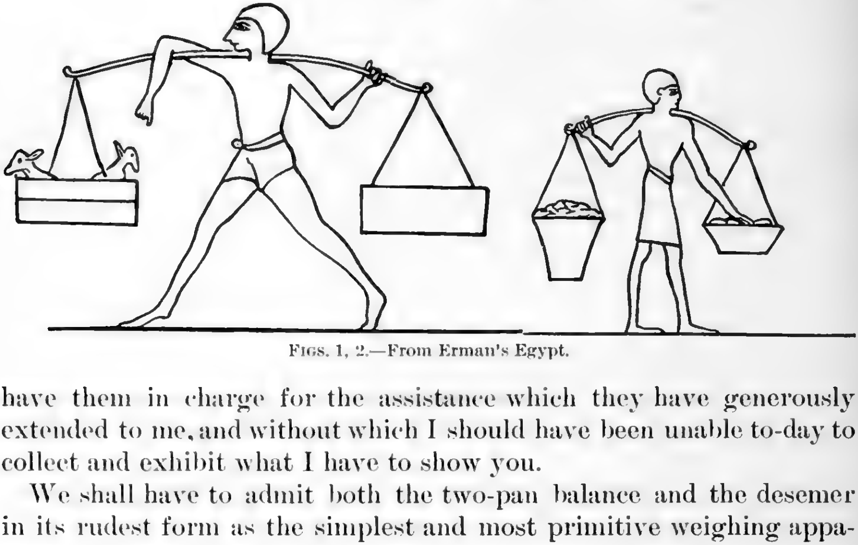
counterpoise, making three essentially separate pieces instead of the two of the desemer. We are to distinguish carefully, then, between

(1) The desemer, with fixed weight and shifting fulcrum, not necessarily having more than two separate pieces, and

(2) The Roman balance, or common steelyard, with shifting weight and fixed fulcrum, necessarily having three pieces at least.

Although the desemer is the subject of the present communication, yet in order to form some rational conjecture concerning the course of its evolution, to comprehend the relation between the three kinds of historical balances (the modern spring balances, aneroid balances, torsion balances, horizontal balances, hydrometer balances, etc., being left out of account), and to decide whether or not the two-pan balance can be considered as the first step toward the unequal-armed balances, it will be necessary to begin by studying the two-pan balance.

We shall be forced to rely, as I have said, almost exclusively upon comparisons between objects in the collections; and before going further it behooves me to express my grateful thanks to those who have them in charge for the assistance which they have generously extended to me, and without which I should have been unable to-day to collect and exhibit what I have to show you.



FIGS. 1, 2.—From Erman's Egypt.

We shall have to admit both the two-pan balance and the desemer in its rudest form as the simplest and most primitive weighing apparatus. Indeed, it is probable that both inventions are primeval and that they were made by different peoples at different times. The invention was easy to make. Many occupations had made it clear that if a bar be in any way supported in the middle, both ends must be equally loaded in order to bring it into the horizontal position. The neck yoke or portage bar, so often seen on ancient Egyptian walls (figs. 1 and 2), or the plank resting on a narrow support, the delightful seesaw of children, called in America a "tilt," in Germany a "wippe," constitutes a ready-made equal-armed balance as soon as anybody thinks of putting it to that use.

Wilkinson, in his Ancient Egyptians, gives a drawing of a goldsmith, after the picture found at Beni-Hassan. It shows two men occupied in weighing gold rings. The figure of the balance seems to represent about the simplest possible equal-armed scales. Fig. 4, albeit a symbolical representation from the classical age of Greece, appears to corroborate the inference from fig. 3 that the primitive equal-armed balance was supported from below.[1] That arrangement, however, did not long prevail, for soon the beam begins to be suspended from a central axis. For a time there was no contrivance, such as a tongue, by which the horizontal position of the beam would be directly and unmistakably shown. On the great amphora of the Taleides (fig. 5), dating perhaps from the sixth century before Christ, such a balance is figured. Instead of a tongue there is a simple crosspiece serving to limit the motion of the beam. Equilibrium in weighing out a predetermined amount of goods would be shown by the beam beginning to swing freely, for the lowest part of the crosspiece is on the side of the goods pan, so that the weight pan would be prevented from sinking too much when it overbalanced the other.

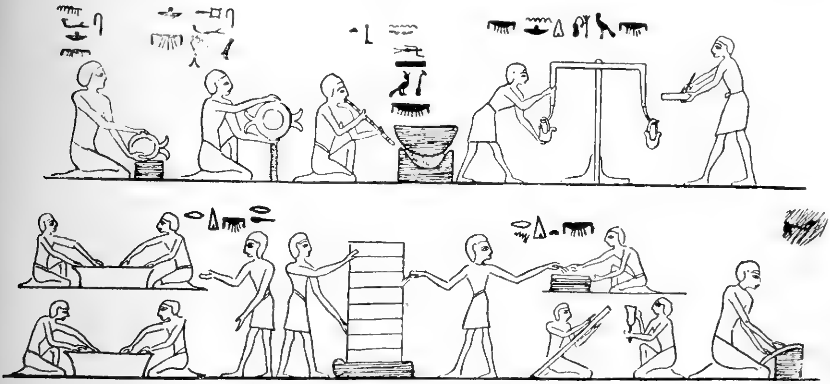


FIG. 3.—From Wilkinson's Ancient Egyptians.

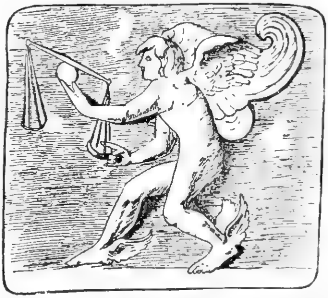


FIG. 4.—From Baumeister's Monuments of Classical Antiquity.

The same object was accomplished by the Egyptians more ingeniously (fig. 6). One arm of the balance passed loosely through a ring which hung upon a round rod above the beam and parallel to it. This rod was often in the form of the hind leg of a baboon that crowned the balance as an image of Thoth, the ordainer of weights and measures, and god of time. Below the ring hung a short plummet. When this plummet and ring were free the beam did not touch the ring, and the

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[1] No. 3 is prevented from upsetting by elbows in the arms, and No. 4 by rolling on a cylinder.—Tr.

weight must be correct. This ring prevented either pan from sinking too far.

Neither of these arrangements allowed the beam more than a very limited play, and from this it may be inferred that they lacked one of the prime requisites of a good balance, namely, that the equilibrium should be stable, so that when unloaded or carrying equal loads the beam should tend to return to the horizontal position, however far it might have been displaced. A later improvement was to suspend the beam by a ring attached to its upper side in the middle, as is seen in fig. 7, from Egypt, and fig. 9, from Japan. The same mode of suspension was employed in the corresponding stage of development of the balance in ancient Greece and Rome.

FIG. 5.—From Baumeister's Monuments of Classical Antiquity.

Although the tongue is wanting, being replaced in Egypt by a somewhat differently constructed plummet, yet a fairly complete weighing apparatus has now been reached, since the two prime requisites of small friction and a position of the axis of rotation somewhat above the line of junction of the points of suspension of the pans are both present. That both these conditions must be fulfilled in order that the scales may work well, the reader need not be informed. But whether these important improvements may not have been adopted in the first instance without any clear anticipation of their advantages is at present left undecided. The monuments show that they were in fact adopted, and weighing could be performed very well upon such a balance, provided the weigher were able to judge when the beam was horizontal. In those days, however, as now, many persons were unable to do that, and therefore a further improvement was called for. This was soon supplied by the attachment of a finger or little stick at right angles to the beam, which, passing across a line of some kind, whether in front of it or behind it, or both, should point out any departure from the position of equilibrium. This is what we call the tongue. It is shown in figs. 7 and 8.[1] The Egyptian contrivance taking the place of the tongue, which was constructed of a plumb bob and three strings, answered its purpose as perfectly as the more usual finger rigidly attached to the beam. Only in the horizontal position all the threads are equally taut, and the slightest tilting slackens two of them.

The introduction of the tongue was a great advance. In many cases it showed whether the balance maker understood the theory of the balance. Even if he paid little attention to the friction, yet if he put the axis of rotation in the right place he could weigh pretty well with his balance in spite of all its imperfection, as a balance from Bavaria belonging to the Museum of Costumes shows (fig. 10). It is composed entirely of wood. Even the axis of rotation is made, in the crudest way, of a round stick. Yet it will weigh light objects pretty well, because the axis of rotation is well placed. With 4 pounds in each pan

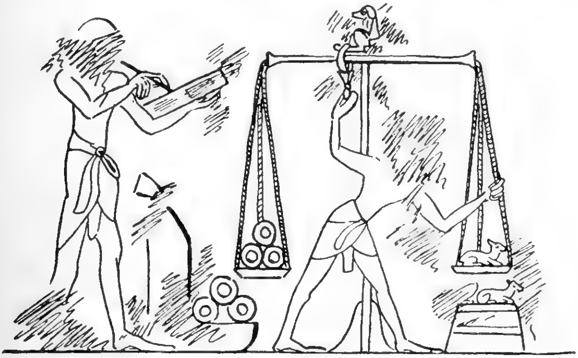

FIG. 6.—From Wilkinson's Ancient Egyptians.

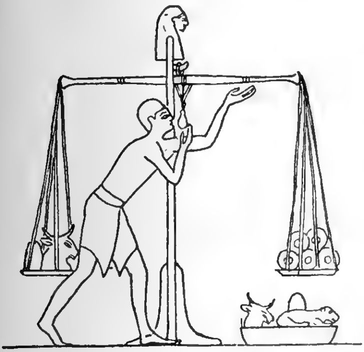

FIG. 7.—From Erman's Egypt.

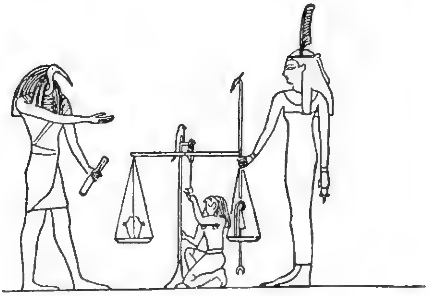

FIG. 8.—From Erman's Egypt.

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[1] So reads Sökeland's text, and certainly in fig. 7 the plumb bob seems to be hung by two strings, between which is a little tongue fixed to the beam. The plummet thus accomplishes the same purpose as the spirit level on a modern balance of precision, but more directly and neatly. A third cord to a plummet would be quite purposeless and un-Egyptian. The tongue between the two cords might be dispensed with, but the arrangement would be far more sensitive with it.—Tr.

(2 kilos) it needs fully one-third of an ounce (10 grams), or one two-hundredth, to turn it sensibly. The regulations of the Prussian standards office would require it to turn with 30 grains (2 grams), or one one-thousandth.


FIG. 9.—From Audsley's Ornamental Arts of Japan. London, 1882.

The giving of a tongue to the balance may be regarded as marking the substantial completion of the invention, and further improvements were confined to details, to diminution of friction, and the like. These last perfected the instrument, and we may now pass to the origination and perfecting of the simplest of the unequal-armed weighing machines, which is the desemer.

The same familiar experiences from which we drew a conjectural account of the first idea of an equal-armed balance suffice for a possible explanation of the origin of the desemer. In seesawing, as in using the porter's yoke, it could not but become well known that very unequal loads could be balanced by shifting the point of support. The idea would also be directly suggested by the use of levers to lift great loads. A desemer which should consist simply of a staff without any special counterpoise and without any graduation would be made as soon as it occurred to the person concerned to apply the otherwise familiar principle to this new purpose. I therefore figure the first desemer as an ordinary stick, with something fastened to the end of it to carry the thing to be weighed.

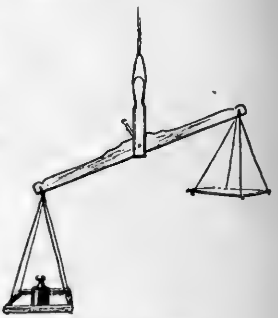
FIG. 10.—Berlin Museum of German Costumes.

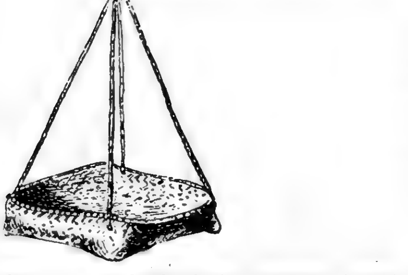
FIG. 11.—Royal Ethnological Museum of Berlin. One-eleventh natural size.

That only a few different weights could be distinguished by so rude an apparatus is evident. But an example from Assam (fig. 11) shows that just such simple apparatus was actually used.

The staff is unloaded, so that, long as it is, but few discriminations of weights could be made with it. But the beginning once made, the inventor had learned how to weigh with no instrument but a stick and a string. In practice it would soon be found that the stick was inconveniently long, and if the object were simply to ascertain whether a mass was up to a standard weight or not, the apparatus could be made handier by simply thickening the free end of the stick, as shown by an example (fig. 12) from Bhutân. This instrument only shows whether a thing does or does not weigh as much as a pound (500 grams). A balance from Assam (fig. 13) is made in the same way. Although it is made of nothing but a cocoanut shell, a stick, and three strings, it is not without a certain elegance. Such simple apparatus could be adapted even to the weighing of gold and silver, as a balance (fig. 14) from the Himalayas shows. It will weigh 6 grams (93 grains) and 3 grams (46 grains). In spite of the unsuitable shape of the staff, we here first find two different weights marked. The use of such a balance would be sure to suggest the making of an instrument for discriminating a greater range of weights. To do that, however, the conical shape of the staff would have to be abandoned because of the tendency of the suspensory thread to slip upon it. Yet it would not do to give up the counterpoising effect of the thickened staff, so that a knob at the end of a cylindrical stick would force itself upon the maker, as in the balance of fig. 17, which comes from Thibet and is said to be a fish scales. By means of the notches cut upon it to mark places for the suspensory thread it will weigh $1\frac{1}{3}$ ounces ($37\frac{1}{2}$ grams), $2\frac{2}{3}$ ounces (75 grams), $12\frac{1}{3}$ ounces (350 grams), $17\frac{2}{3}$ ounces (500 grams), 23 ounces (650 grams).

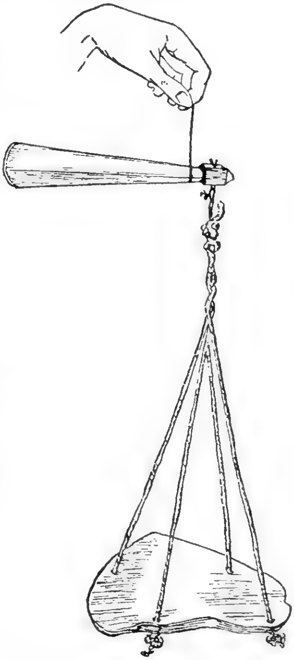
FIG. 12.—Royal Ethnological Museum of Berlin. One-sixth natural size.


FIG. 13.—Royal Ethnological Museum of Berlin.

This is a practical instrument, for the principle of the form and dimensions of a good desemer is followed; but the highest weight that can be ascertained is small. This fault, however, could easily be rectified by loading the knob with lead, iron, sand, or something, as our German desemer (fig. 16) shows. This will weigh up to 30 pounds, first at intervals of 1 pound and for higher weights of 2 and 3 pounds. Simple brass pegs, as everybody knows, running to the end of the staff, show the weights with tolerable accuracy. With this stage of development a handy instrument, sufficient for ordinary purposes, was reached. How very simple such a balance may be is shown by an example (fig. 17) from White Russia, the property of Mr. Bartels. It consists of a stick with a natural knob as counterpoise, and will weigh up to 30 pounds and more in about twenty distinct quantities.

In many places such simple contrivances are used even in the shops. But it must soon be found that the state of dryness or moisture of the wooden knob affects the weight, so that the scale is deranged. In order to meet this difficulty desemers were made with hollow counterpoises, which could be filled with sand or pieces of iron (fig. 18), and thus the balance could easily be corrected. It is also possible that this arrangement served the cheat. On the frontiers desemers were in use which, like that of fig. 19, had two scales, for German and Russian units.

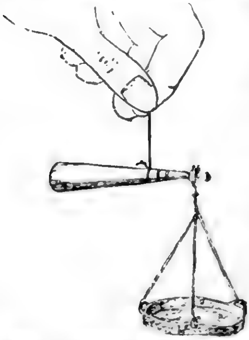

FIG. 14.—Royal Ethnological Museum of Berlin. One-fourth natural size.

All the desemers so far considered are wooden. But desemers were also made of iron, as one from the province of Brandenburg (fig. 20) and one from Tibet prove (fig. 21). This German instrument is only for heavy goods, while the Tibetan runs from 1 ounce (30 grams) to 5½ pounds (2½ kilos). This balance can only have been used for weighing gold, since its tiny pan would not hold such a weight of other material.

We have now made the acquaintance of an entire series of desemers, and have seen that they can be used to weigh from 30 pounds down to a drachm—but not with any one example. The German desemers are confined to large weights; the Thibetan to small ones. The limitations were not, however, universal; for the Romans had desemers, which, in addition to an essential advantage which they share with those of Tibet, also embraced a much more extended series of weights.

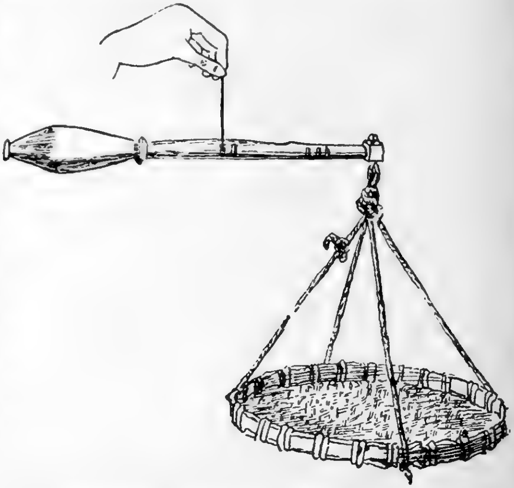

FIG. 15.—Royal Ethnological Museum of Berlin. One-seventh natural size.

Three Roman balances of this description have been brought to light, of which only two, so far as is known, still exist. The finer of these two, shown in fig. 22, is supposed to have come from Chinsi

(Chesium). Although of a peculiar form, it is a regular desemer, having the distinctive characteristics of a fixed counterpoise and movable fulcrum and consisting essentially of two pieces. Shortly after its purchase it was made the subject of communications to the Berlin Archeological Society by Messrs. Robert and Lehmann.[1] This bronze instrument is in the form of a pillar whose capital and base are cut into steps. Springing from the under side of the base is the front half of a panther, finely worked. This is the counterpoise. At the head of the pillar there is an eyelet from which hang three hooks, each terminating in a swan's head. Parallel to the pillar and above it (when the balance is in use) is a straight bridge, flat in the vertical plane, which carries a scale of numbers. For every number there is a notch in the under side of the bridge. Instead of the usual suspensory thread there is a bronze handle, in which a slit or oblong hole incloses the bridge. The lower part of the handle is in the form of a plate, and the lower edge of the hole in it, which edge is horizontal, is sharp enough to enter loosely in the notches in the bridge.

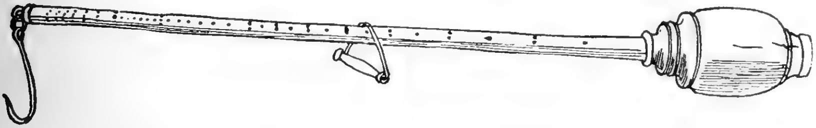

FIG. 16.—Museum of German Costumes. Two-fifteenths natural size.

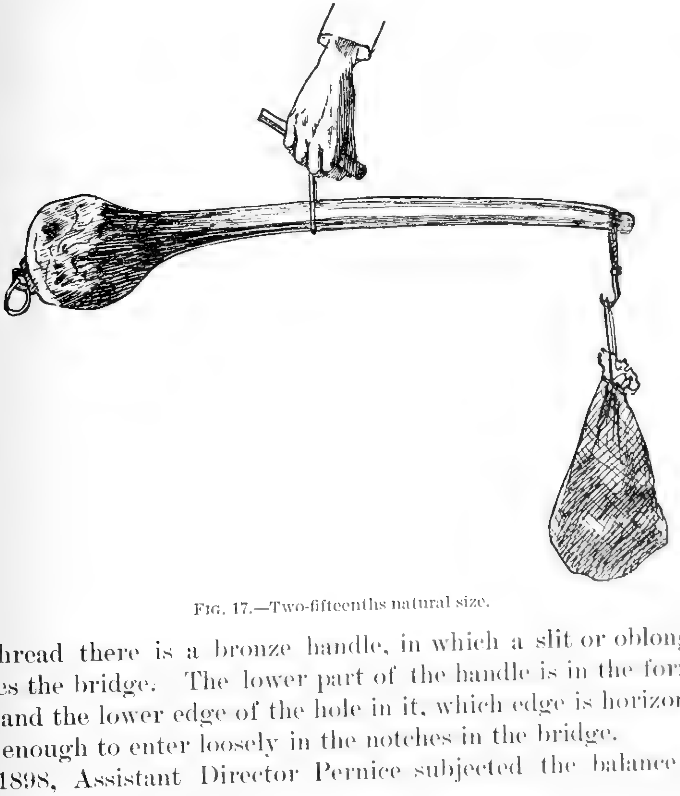

FIG. 17.—Two-fifteenths natural size.

In 1898, Assistant Director Pernice subjected the balance to an

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[1] Archäologischer Anzeiger, 1889, S. 117; 1891, S. 138.

exact examination and communicated his results to the Archeological Society.[1] Direct weighings showed Pernice that the three hooks must have carried a pan weighing 14 ounces avoirdupois (400 grams, or a Roman pound and a quarter), for this makes the weights agree with the numbers engraved above the notches. The letter A marks the zero, and the pan must balance when the fulcrum is placed there. The scale begins with a Roman ounce (0.96 ounce avoirdupois, 27.288 grams; and the pound of a part of Etruria was, according to Hultsch, the same as the Roman pound). Then follow 2, 3, 4, 5, 6, 7, 8, 9, 10, 12 ounces, or 1 Roman pound. The differences now begin to be greater; for the numbers run 1, $1\frac{1}{6}$, $1\frac{1}{3}$, $1\frac{1}{2}$, $1\frac{2}{3}$, 2, $2\frac{1}{4}$, $2\frac{1}{2}$, 3, $3\frac{1}{2}$, 4, $4\frac{1}{2}$, 5, 6, 7, 8, 9, 10, 12, 15, 20, 25, 30, 40 pounds.

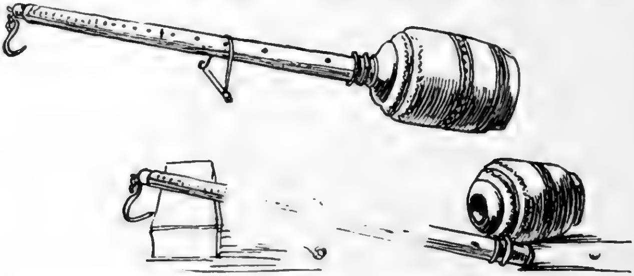

FIG. 18.—Museum of German Costumes. Two-fifteenths natural size.

The second Roman desemer is now, as Mr. Pernice shows, in Palermo.[2] Except that it is provided with a bridge, it resembles the iron desemer of Brandenburg (fig. 20). But its scale showed that it gave weights even more exactly than the Clusium balance. As before letter A marks the zero, placing the fulcrum at which before weighing, equilibrium must be produced before the goods to be weighed are attached. The scale then proceeds from 1 ounce by single ounces to 2 pounds, and then as follows: $2\frac{1}{4}$, $2\frac{1}{2}$, $2\frac{3}{4}$, 3, $3\frac{1}{2}$, 4, $4\frac{1}{2}$, 5, 6, 7, 8, 10, 12, 15 pounds.

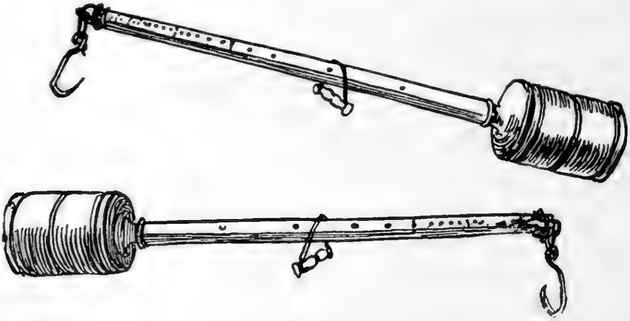

FIG. 19.—Museum of German Costumes. Two-fifteenths natural size.

The third Roman desemer is known only from a figure in a Paris MS.

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[1] Jahrbuch des Kaiserl. archäolog. Institutes, Vol. XIII, 1898, 2d part.

[2] A figure of this desemer is to be seen in the Annali for 1889, Tavola L.

It was quite similar to the other two, but weighed more exactly than the Clusium balance and ran up to 40 pounds. But both this and the Palermo balance are far inferior in finish. The Clusium balance probably dates from the third or fourth century before Christ.

Pernice's description of this balance on the archeological and metrological sides is exhaustive. But as a member of the developmental series of those balances called desemers, it then appears that a great technical advance is made over the instruments previously considered. I refer to the raising of the bridge above the staff which carries the load and counterpoise. Nothing like this has been seen in any of the desemers previously examined. Why did the Roman deface his elegant instrument with this unbeautiful bridge? At first sight one might be inclined to suppose that it was simply to make the numbers show better. But that hypothesis will not answer. The bridge, with the scale, might just as well have carried the load and counterpoise too. There must have been some other reason, and a good reason there is.

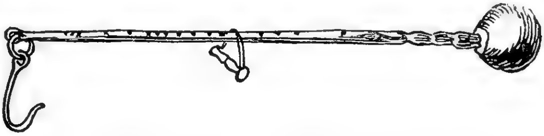

Fig. 20.—Museum of German Costumes, etc. Two-fifteenths natural size.

The two prime requisites of a good balance are, as is well known, that the friction shall be as small as possible and that the equilibrium shall be stable whether the balance is loaded or not. The center of gravity must, for that purpose, be below the point of support.[1]

Now German desemers, as we know by experience, remain still when in equilibrium without oscillating. They can not oscillate, for the moment the departure from equilibrium is sufficient to overcome friction they turn, with no tendency to return, and slide down on one side or the other, because the point of support is below the center of gravity. If a pound is in equilibrium on the desemer, and one side or other is pressed down,

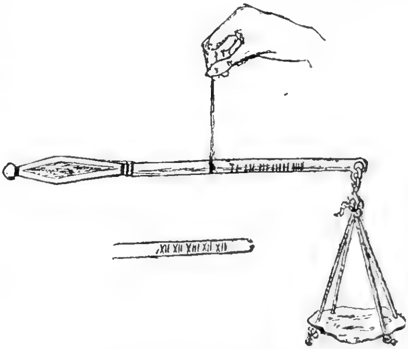

Fig. 21.—Royal Ethnological Museum of Berlin. One-sixth natural size.

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[1] If it is too far below, the balance will not be sensitive enough; that is, its position of equilibrium will be too little changed by a small change of the weight in one pan. If the center of gravity is too close below the point of support, the oscillations and with them the whole operation of weighing will become slow and tedious. In fact, as long as the friction remains the same the excess of weight in one pan required to overcome

instead of tending to restore itself (as an oscillating balance will), it tends to go farther, so that the side pressed down appears to grow heavier. Such behavior (called "upsetting" in English) is a grave fault, for, in order to weigh, it is necessary not only to shift the fulcrum back and forth, but, all the while, to take care that the bar is horizontal.

The Romans perfectly understood this fault. In saying this it is assumed that the balance of Clusium does not represent the first invented form. It must, surely, have had its forerunners, which doubtless resembled the German desemers in respect to the position of their point of support, and therefore shared their inconvenience. In order to use such a balance in retail trade it was necessary to have one which would come back to the position of equilibrium. It is one thing to weigh a given thing or collection of things, which is almost all that our

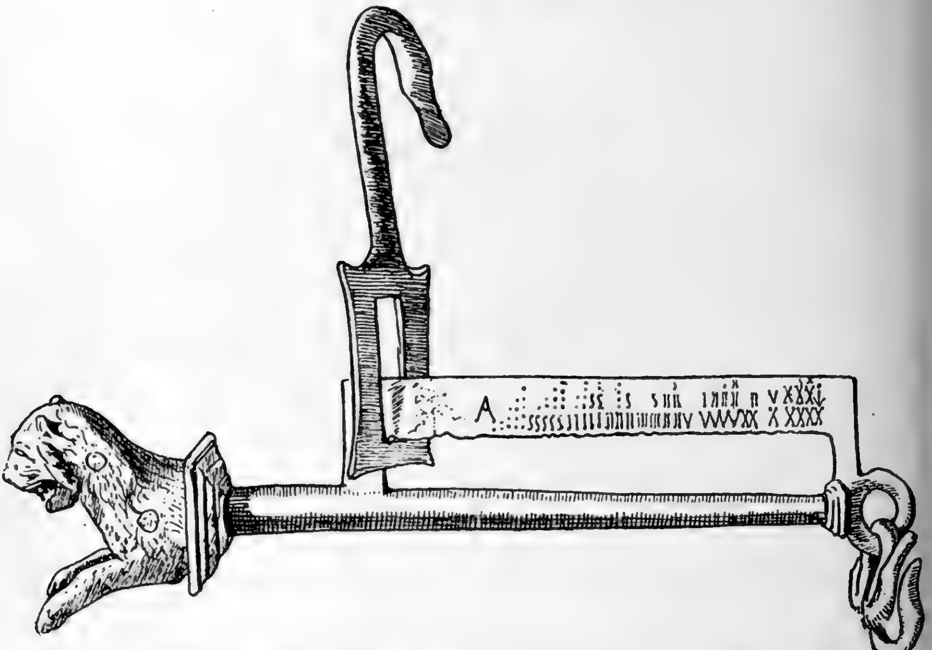

FIG. 22.—Antiquarium, Berlin. Reproduced from Yearbook of German Imperial Archeological Institute, Vol. XIII, 1898. One-third natural size.

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the friction remains just the same whatever the height of the fulcrum; for though the weight acts more nearly at right angles to the radius from the center of rotation to the center of gravity when they are closer together, yet the leverage is smaller in the same proportion. It is, therefore, generally better to rely upon optical means, such as a very long tongue, to show small departures from equilibrium, rather than to bring the center of gravity so near the axis of rotation that the friction can arrest the balance in any sensibly oblique position. But the most intolerable fault is to have the center of gravity above the axis of rotation, so that there is a tendency to "upset."—Tr.

German desemers are used for, and quite another to weigh out a desired quantity of any commodity, which is the common problem of the retailer. If it is desired to weigh a goose, or several fish in a net, it can be done with a common desemer, with the requisite skill. But to weigh out 5 pounds of pease with a desemer is a difficult task, indeed, for none can be taken out or put in while the balance is in action, because it does not oscillate at all, but simply "upsets" as soon as the departure from equilibrium is sufficient to overcome the friction Now, since it was the custom in ancient Rome to use balances on the principle of our desemers in shops, as the Clusium balance proves, it follows that men were directly required to think out improvements whereby the desemers, when loaded, should oscillate. Now the two-pan balances made by the Romans were constructed essentially right. The position of the axis of rotation was correct, which is the essential condition for the oscillation of the balance. In order to make their desemers oscillate, and so make them practicable for shopkeepers, the Romans introduced the bridge above the pillar. The lower end of the bronze handle from which the other piece hangs is quite above the center of gravity of the latter, so that a fine oscillation and return from every oblique position must have resulted. You can see how the bridge works by simply attaching one made of wire to the common German desemer, when you see how much better it works and how well it oscillates. The ancient Romans, doubtless, attached that ugly bridge to their beautiful balance just to cure it of that quite intolerable fault. It looks like an exerescence upon the original design.

If you ask why desemers so seldom are furnished with such bridges, the answer is it is not the only requirement that a balance should oscillate; it must also be sensitive. It has already been remarked that a good balance ought to have its point of support only a little above the common center of gravity of the beam, the load (placed where attached), and the counterpoise. The higher the point of support the more the sensibility is lost.[1] For example, this German desemer leaves the horizontal position with an overload of one-fifth or one-sixth of an ounce (5 or 6 grams), but, with the bridge, it needs about half an ounce (15 grams) to give a perceptible turning. So it is with the Clusium balance; it needs a third of an ounce to turn it perceptibly, so that it never could have answered for fine weighing. In point of sensibility, therefore, this balance left much to be desired.

Whether the Romans ever improved any further upon this type of balance, or passed directly to the steelyard with the running weight, or to this latter through the two-pan balance with a rider, such as has been found in Pompeii, remains undecided. The sensibility of the Clusium balance certainly might have been greatly increased without

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[1] Fig. 17 shows a desemer which must combine sensibility with rapid weighing and which certainly would not upset, but would oscillate.—Fr.

spoiling the oscillations. Thus the sensibility might easily have been made four times as great, only doubling the period of oscillation. The Thibetan desemers show this. That of fig. 15, for example, has a general resemblance to the German desemers, except for having a pan. But the mode of suspension by the string is altogether different. Our desemers are balanced on the string, which is stretched straight by the handle, while the Thibetan string forms a sling which closes upon the staff. This alone would suffice to raise the axis of rotation to about the middle of the staff; but, in addition, grooves are cut in the staff of such a form as to raise the turning axis still higher. The result is that the Thibetan desemers oscillate; and, in fact, their sensibility is quite high, considering the simplicity of their construction. We have seen that they would show distinctly the effects of very small weights. Even our German desemer, hung in the same way, will show a departure from equilibrium of only one-seventh to one-tenth of an ounce (3 or 4 grams). I hardly need say that cutting the grooves involves the displacement of the scale. It will now be placed on the side of the staff, where it can be read off during the operation of weighing. It is not necessary, as with our desemers, to turn the thing over and look on the under side. (The desemer of fig. 17 certainly would not upset.)

We now come to the puzzling question, how it can be that the German desemers are so much ruder than those of Thibet. As far as I can see there can be no mistake about the fact, though it is so astounding as to raise doubt at first. I have examined about fifty desemers, of which thirty were our property and were in actual use at the time we acquired them. The mode of weighing on strings is the same in all, and the scale is always on the under side. Indeed, the wooden handle for the string can not be managed in any other way. The Russian desemers were used in the same way.[1] Why did not we, like the Thibetan mountaineers, discover this simple improvement? My opinion is that it was because we were not forced to it.

In conclusion, let me call attention to one thing more about the Clusium balance. We have seen that this weighs down to a single ounce. Now, in the Altmark, the desemer is called "uenzel." Before the discovery of the Clusium balance no satisfactory explanation of this name had ever been suggested. No German desemers capable of weighing to an ounce are known. But perhaps it is now permissible to infer that in the Altmark, which is very rich in Roman remains, balances were formerly in use which, like that of Clusium, weighed to ounces, and that, as the steelyard is called in German a "pfunder," so the name of these balances passed over to the ordinary desemers and has been retained to this day.

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[1] But not that of fig. 17, which must oscillate and has a string.—Tr.

MUTUAL HELPFULNESS BETWEEN CHINA AND THE UNITED STATES.[1]

By His Excellency Wu Ting-Fang,

Chinese Minister to the United States.

Trade, which lies at the foundation of international intercourse, has an eminently selfish origin. It is a constant maneuver on the part of men to sell dear and buy cheap. Since each party in a commercial transaction seeks only his own advantage, it was for a long time thought that one of them could gain only at the expense of the other. Thus the "mercantile system," which for centuries held Europe spellbound, made gold-getting the end and aim of all commercial activities. The promotion of friendly relations with the object of securing an exchange of benefits was not considered of even secondary importance. Then came the navigation laws, which had for their avowed purpose the crippling of all rival shipping by laying a heavy tax upon the carrying trade of foreigners. Though such measures are no longer considered advisable in the commercial world, their baleful effects are still felt in the political thought of the present time.

Nations now enter into friendly relations with each other because it is believed that both sides are benefited by such relations. Their transactions can not be one-sided affairs, for the simple reason that it takes two to make a bargain. If one party is dissatisfied with the arrangement, the other party will not long have an opportunity to enjoy its benefits.

Confucius was once asked for a single word which might serve as a guiding principle through life. "Is not reciprocity such a word?" answered the great sage. "What you do not want done to yourself, do not do to others." This is the "golden rule" which should govern the relations of man to man. It is the foundation of society. It lies at the bottom of every system of morality and every system of law. If it holds good with respect to individuals, it ought to hold good with respect to nations, which are but large aggregations of individuals. Therefore, if permanent relations are to be established between two nations, reciprocity must be the keynote of every arrangement entered into between them.

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[1] Reprinted by permission from the North American Review, No. DXXIV, July, 1900.

Having recognized this great principle of international intercourse, how shall we apply it to the case of China and the United States in such a manner as to result in mutual helpfulness? Assuredly, the first thing to do is to take a general survey of the situation and see what are the present needs of each country. Then we shall perceive clearly how each may help the other to a higher plane of material development and prosperity.

The United States now has its industrial machinery perfectly adjusted to the production of wealth on a scale of unprecedented magnitude. Of land, the first of the three agents of production enumerated by economists, the United States is fortunately blessed with an almost unlimited amount. Its territory stretches from ocean to ocean, and from the snows of the Arctic Circle to the broiling sun of the Tropics. Within these limits are found all the products of soil, forest, and mine that are useful to man. With respect to labor, the second agent of production, the United States at first naturally suffered the disadvantage common to all new countries. But here the genius of the people came into play to relieve the situation. That necessity, which is "the mother of invention," substituted the sewing machine for women's fingers, the McCormick reaper for farm hands, the cotton gin for slaves. The efficiency of labor was thereby multiplied, in many cases, a hundredfold. The ingenious manner in which capital, the third agent of production, is put to a profitable use, is equally characteristic of America. It is well known that there is an enormous amount of capital in this country seeking investment. Everyone who has a little to invest wishes to obtain as large a return as possible. Since competition reduces profits, the formation of industrial combinations, commonly called trusts, is for the capitalist the logical solution of the difficulty. These enable the vast amount of capital in this country to secure the best results with the greatest economy. Whether they secure "the greatest good to the greatest number" is another matter.

The development of the resources of the United States by the use of machinery and by the combination of capital has now reached a point which may be termed critical. The productive power of the country increases so much faster than its capacity for consumption that the demand of a population of 75,000,000 is no sooner felt than supplied. There is constant danger of overproduction, with all its attendant consequences. Under these circumstances, it is imperative for the farmers and manufacturers of the United States to seek an outlet for their products and goods in foreign markets. But whither shall they turn?

At first sight Europe presents perhaps the most inviting field. Both blood and association point in this direction. But here the cottons of Lowell would have to compete with the fabrics of Manchester. The silk manufactures of Paterson would stand small chance of supplanting the finished products of Lyons. The sugar of Louisiana would encounter a formidable rival in the beet-sugar of Germany. England could probably better afford to sell her coal and iron cheaper than Pennsylvania, and Russia could supply European markets with wheat and petroleum as well as could Ohio and Indiana. Competition would be keen and destructive.

Central and South America have as yet too sparse a population for the immense territory they cover to meet the conditions of a market for American goods. Some decades must elapse before American farmers and manufacturers can look to that quarter for relief.

But on the other side of the Pacific lies the vast Empire of China, which in extent of territory and density of population exceeds the whole of Europe. To be more particular, the province of Szechuen can muster more able-bodied men than the German Empire. The province of Shantung can boast of as many native-born sons as France. Scatter all the inhabitants of Costa Rica or Nicaragua in Canton, and they would be completely lost in that city's surging throngs. Transport all the people of Chile into China and they would fill only a city of the first class. Further comparisons are needless. Suffice it to say that China has her teeming millions to feed and to clothe. Many of the supplies come from outside. The share furnished by the United States was considerably larger last year than ever before, and might be greatly increased. According to the statistics published by the United States Government, China in 1899 took American goods to the value of $14,437,422, of which amount $9,844,565 was paid for cotton goods. All the European countries combined bought only $1,484,363 worth of American cotton manufactures during that same period. The amount of similar purchases made by the Central American States was $737,259; by all the South American countries, $2,713,967. It thus appears that China is the largest buyer of American cotton goods. British America comes next in the list with purchases amounting to $2,759,164. Cotton cloth has a wide range of uses in all parts of the Chinese Empire, and it is almost impossible for the supply to equal the demand.

Up to the year 1898 cotton goods and kerosene were the only articles imported from the United States in large enough quantities to have a value of over $1,000,000. But I notice in the statistics published by the United States Government for the year 1899 that manufactures of iron and steel have also passed that mark. This is due to the fact that China has now begun in real earnest the work of building railroads. The demand for construction materials is great. The value of locomotives imported last year from the United States was $732,212.

Besides the articles mentioned there are many others of American origin which do not figure in the customs returns as such. These find their way into China through adjacent countries, especially Hongkong.

At least three-fourths of the imports of Hongkong, notably wheat, flour, and canned goods, are destined for consumption in the Chinese mainland.

Such is the present condition of trade between the United States and China. That trade can be greatly extended. Let the products of American farms, mills, and workshops once catch the Chinese fancy, and America need look no farther for a market. The present popularity of American kerosene illustrates the readiness of the Chinese to accept any article that fills a long-felt want. They have recognized in kerosene a cheap and good illuminant, much superior to their own nut oil, and it has consequently found its way into distant and outlying parts of the Empire, where the very name of America is unknown. Stores in the interior now send their agents to the treaty ports for it. In the same way foreign-made candles, because cheaper than those of home make, are selling easily in China. I would suggest that American farmers and manufacturers might find it to their advantage to study the wants and habits of the Chinese and the conditions of trade in China.

Thus we see that China can give the United States a much-needed market. What, on the other hand, can the United States do for China? Let us consider China's stock of the three requisites for the production of wealth—land, labor, and capital.

The Chinese Empire embraces a continuous territory which stretches over 60 degrees of longitude and 34 degrees of latitude. Nature has endowed this immense region with every variety of soil and climate, but has, however, scattered her bounties over it with an uneven hand. That portion which comprises the eighteen provinces of China Proper, extending from the Great Wall to the China Sea, and from the Tibetan plateau to the Pacific Ocean, is more highly favored than the rest. Whenever China is mentioned it is generally this particular portion of the Empire that is meant. On this land hundreds of generations of men have lived and died without exhausting its richness and fertility. There remains for generations to come untold wealth of nature lying hidden within the bowels of the earth. The mines of Yunnan, though they have for centuries supplied the Government mints with copper for the coining of those pieces of money commonly known as cash, only await the introduction of modern methods of extraction to yield an annual output as large as that of the famous Calumet and Hecla mines. The sands of the Yangtze, washed down from the highlands of Tibet, contained so much gold that that part of its course as it enters the province of Szechuen is called the River of Golden Sand. Much more important than these, however, are the deposits of coal which underlie the surface formation of every province. All varieties of coal are found, from the softest lignite to the hardest anthracite, and in such quantities that, according to the careful estimate of Baron Richtofen, the famous German traveler and geologist, the province of Shansi alone can supply the whole world, at the present rate of consumption, for three thousand years. In most cases beds of iron ore lie in close proximity to those of coal and can hence be easily worked and smelted. In short, the natural resources of China, both in variety and quantity, are so great that she stands second to no other nation in potential wealth. To reduce this potentiality to actuality is for her the most important question of the hour. For this purpose she has an almost unlimited supply of labor at her command.

Every village can count its thousands of laborers, every city its tens of thousands. Experience proves that the Chinese as all-round laborers can easily distance all competitors. They are industrious, intelligent, and orderly. They can work under conditions that would kill a man of a less hardy race; in heat that would suit a salamander or in cold that would please a polar bear, sustaining their energies through long hours of unremitting toil with only a few bowls of rice.

But have the Chinese sufficient capital to carry on their industrial operations? They are a nation of shopkeepers. What capital they have is usually invested in small business ventures. It is their instinct to avoid large enterprises. Thus the capital in the country, though undoubtedly large, may be likened to a pile of sand on the beach. It has great extent, but is so utterly lacking in cohesion that out of it no lofty structure can be built. Before China can be really on the high road to prosperity it must find means of fully utilizing every economic advantage that it has. Modern methods are its greatest need. Here is America's opportunity.

The Yankee is never seen to better advantage than when experimenting with a new idea on a colossal scale. To direct vast or novel enterprises is a perfectly new experience to the Chinaman. Give him a junk and he will with ease ride out the fiercest typhoon that ever lashed the seas. But give him an ocean leviathan of the present day, with its complicated engines, dynamos, compasses, and other modern appliances for navigating a ship, and he will be truly "all at sea" in knowing how to handle it, even in a dead calm.

Of all public works, China has most pressing need of railroads. Only ten years ago it would have been difficult to convince one man in ten of the immediate necessity for the introduction of railroads into all the provinces of the Empire. To-day, at least nine out of every ten believe that railroads ought to be built as fast as possible. This complete change of public opinion within so short a time shows perhaps better than anything else how fast China is getting into the swing of the world's forward movement. There are at present only about 400 miles of railroad open to traffic throughout the whole country, and all the lines building and projected foot up to 5,000 or 6,000 miles more.

China proper covers about as many square miles as the States east of the Mississippi. Those States, with a population of 50,000,000, require 100,000 miles of railroad to do their business. China, with a population eight times as large, would naturally be supposed to need at least about an equal mileage of roads for her purposes. It would not be strange if the activity in railroad construction in the United States soon after the civil war should find a parallel in China in coming years.

The building of railroads in China does not partake of the speculative character which attended the building of some of the American roads. There are no wild regions to be opened up for settlement, no new towns to be built along the route. Here is a case of the railroad following the population, and not that of the population following the railroad. A road built through populous cities and famous marts has not long to wait for traffic. It would pay from the very beginning.

The first railroad in China was built for the transportation of coal from the Kaiping mines to the port of Taku. I was chiefly instrumental in securing its construction. The line, though in an out-of-the way corner of the Empire, proved so profitable from the very start that it was soon extended to Tientsin and Pekin in one direction, and to Shanhaikwan, the eastern terminus of the Great Wall, in the other. Not long ago it was thought advisable to build a branch beyond Shanhaikwan to the treaty port of Newchwang. This branch has been completed and will soon be opened to traffic. Minister Conger, in a recent letter to the State Department, says that the road now pays a dividend of 14 per cent on the whole capital invested, and that when the entire line is open a dividend of 30 per cent is expected. The era of railroad building in China may be said to have just dawned. China desires nothing better than to have Americans lend a hand in this great work.

It gave me great pleasure two years ago to obtain for an American company a concession to build a railroad between Hankow, the great distributing center of central China, and Canton, the great distributing center of south China. The line is to connect with the Lu-Han line on the north and with the Kowloon line on the south, and throughout its whole length of more than 900 miles will run through opulent cities, fertile valleys, and cultivated plains. The construction of such a line by Americans through the heart of China can not fail to bring the people of the two countries into closer relations.

Besides railroads, there are other public works which China must undertake sooner or later. Among them are river and harbor improvements, city water supplies, street lighting and street railways. Owing to the traditional friendship between the two countries our people are well disposed toward Americans. They are willing to follow their lead in these new enterprises, where they might spurn the assistance of other people with whom they have been on less friendly terms in the past.

Such being the economic interdependence of China and the United States what policy should each country pursue toward the other in order to gain the greatest good from that relationship? In my judgment true reciprocity is impossible unless each country has perfect confidence in the other and displays on all occasions a desire for fair play and honest dealing.

Now, reciprocity demands the "open door." China long ago adopted that policy in her foreign intercourse. She has treaty relations with all the European powers, together with the United States, Brazil, Peru, Mexico, Japan, and Korea, All these are equally "favored nations" in every sense of the term. The Swede and the Dane enjoy the same rights, privileges, immunities, and exemptions with respect to commerce, navigation, travel, and residence throughout the length and breadth of the Empire as are accorded to the Russian or the Englishman. Any favor that may be granted to Japan, for instance, at once inures to the benefit of the United States. Indeed, China in her treatment of strangers within her gates has in a great many respects gone even beyond what is required by international usage. According to the usual practice of nations no country is expected to accord to foreigners rights which are not enjoyed by its own subjects or citizens. But China has been so long accustomed to indemnify foreigners who have fallen victims to mob violence that she is looked upon in a sense as an insurer of the lives and property of all foreigners residing within her borders. To such an extent is this idea current among foreigners in China that some years ago an American missionary in the Province of Shantung, who happened to have some articles stolen from his house in the night, estimated his loss at $60, and actually sent the bill through the American minister at Pekin to the Foreign Office for payment. The Chinese tariff also favors foreigners resident in China much more than it does the Chinese themselves. Most articles imported for the use of foreigners are on the free list. Such is the treatment which Americans, in common with the subjects and citizens of other foreign powers, receive in China.

Justice would seem to demand equal consideration for the Chinese on the part of the United States. China does not ask for special favors. All she wants is enjoyment of the same privileges accorded other nationalities. Instead, she is singled out for discrimination and made the subject of hostile legislation. Her door is wide open to the people of the United States, but their door is slammed in the face of her people. I am not so biased as to advocate any policy that might be detrimental to the best interests of the people of the United States. If they think it desirable to keep out the objectionable class of Chinese, by all means let them do so. Let them make their immigration laws as strict as possible, but let them be applicable to all foreigners. Would it not be fairer to exclude the illiterate and degenerate classes of all nations rather than to make an arbitrary ruling against the Chinese alone? Would it not be wiser to set up some specific test of fitness, such as ability to read intelligently the American Constitution? That would give the Chinese a chance along with the rest of the world, and yet effectually restrict their immigration. Such a law would be practically prohibitory as far as all except the best educated Chinese are concerned, for the reason that the written language of the Chinese is so entirely different from the spoken tongue that few of the immigrants would be able to read with intelligence such a work as the American Constitution. Nevertheless, a law of that kind would be just in spirit and could not rouse resentment in the Chinese breast.

Since the law and the treaty forbid the coming of Chinese laborers I must do all I can to restrict their immigration. I should, however, like to call attention to the fact that the Chinese exclusion act, as enforced, scarcely accomplishes the purpose for which it was passed. It aimed to provide for the exclusion of Chinese laborers only, while freely admitting all others. As a matter of fact, the respectable merchant, who would be an irreproachable addition to the population of any country, has been frequently turned back, whereas the Chinese highbinders, the riffraff and scum of the nation, fugitives from justice and adventurers of all types, have too often effected an entrance without much difficulty. This is because the American officials at the entrance ports are ignorant of Chinese character and dialects and can not always discriminate between the worthy and the unworthy. Rascals succeed in deceiving them, while the respectable but guileless Chinese are often unjustly suspected, inconveniently detained, or even sent back to China. A number of such cases have been brought to my attention. It must not be supposed, however, that I blame any official. In view of their limited knowledge of Chinese affairs, it is not strange that the officials sometimes make mistakes. The Americans judge us wrongly, just as we often misjudge them. This unpleasant state of things is to be deplored, and I would suggest that difficulties might be avoided if the regular officials, in passing on immigrant Chinamen, could have the assistance of Chinese consuls, or people fitted by training and experience in China for the discharge of such duties.

Great misunderstanding exists in the United States in regard to Chinese questions. There is a current fear that if all restrictions on Chinese immigration were removed, the United States would be flooded with my countrymen. Inasmuch as China contains some 400,000,000 inhabitants, a wholesale emigration would certainly be a serious matter for the people of the country to which they removed. But there is no danger of such a calamity befalling the United States. Those who view it with alarm only show how profoundly ignorant they are of Chinese character. One of the most striking features of the conservatism of the Chinese is their absolute horror of travel, especially by sea. They regard any necessity for it as an unmitigated evil. They do not often visit neighboring towns, much less adjoining provinces or foreign countries. So pronounced is their prejudice against travel that, until they could be educated into a different view, Chinese railroads would for the first few years have to depend for their profits on freight rates rather than passenger fares. To the American or Englishman who proceeds to go abroad as soon as he has accumulated a little money, their state of mind may seem incomprehensible, but it is nevertheless a fact that must be taken into account.

How, then, is the presence of so many Chinese in America explained? By the fact that some forty years ago, when the Pacific railway was building, there was great scarcity of laborers. Agents went to China and induced a considerable number of Chinese to come to this country and assist in the construction of the railroad. After their work was done most of them returned home, taking their earnings with them. They told their relatives of the exceptional opportunities for making money in this country, and they in turn decided to seek their fortunes here. Were it not for this circumstance, there would be no more Chinese in this country than there are in Europe, where wages are also much higher than in China. As it is, all who are in the United States are from the province of Canton, and they come from two or three places only of that one province.

It has been said that the rules of international intercourse as observed by Western nations among themselves are not applicable to intercourse with Eastern nations. True it is that the people of the East speak different languages and have different customs, manners, religions, and ways of thinking from the people of the West. But the rule of contraries is by no means a safe guide through the intricacies of social observances. By disregarding the common civilities of life, which are considered very important in China, and by assuming a lofty air of superiority, foreigners frequently make themselves unpopular in China. Americans have the reputation there of being abrupt, English dictatorial. In recent years competition in trade with people of other nationalities has reduced their profits and forced them, for the sake of obtaining custom, to be more suave in their manners. Foreigners are sometimes guilty, also, of practicing all sorts of tricks upon the unsuspecting natives. It should be remembered that the Chinese standard of business honesty is very high. The "yea, yea" of a Chinese merchant is as good as gold. Not a scrap of paper is necessary to bind him to his word. Friendly feeling between the people of China and those of the United States would be greatly promoted if the Americans would always remember, in whatever dealings they may have with the Chinese, that "Honesty is the best policy."

I believe that the Western nations want to treat the people of the Orient fairly. It is gratifying to see that Japan has been able to revise her exterritorial treaties, and it speaks well for the fairmindedness of England and other countries that they have thrown no obstacles in her way. I hope that the day will soon come when China may follow in her footsteps.

In the meantime China observes with interest that the planting of the Stars and Stripes in the Philippine Islands will make the United States her neighbor in the future, as she has been her friend in the past. It is her earnest hope that the United States will make no attempt to bar Asiatics from her new shores, but that she will seize this opportunity to strengthen friendly relations of mutual helpfulness between the two countries. No other nation has a stronger claim to the confidence of China than has the United States. The very first article of the first treaty concluded between the two nations provides that there shall be peace and friendship between them and between their people. Through a half century of intercourse no untoward circumstance has interrupted those amicable relations. More than once the United States Government has used its good offices to promote Chinese interests and welfare. Nations, like individuals, appreciate favors, and, like them also, resent indignities. The sentiment of good will entertained by the Government and people of China toward the Government and people of the United States is strong and profound because of the long, unblemished past, but underneath it all there is, I am sorry to say, a natural feeling of disappointment and irritation that the people of the United States deal now less liberally with the Chinese than with the rest of the world. If the best guarantee of friendship is self-interest, surely the friendship of a nation of 400,000,000 people ought to be worth cultivating. China does not ask for much. She has no thought of territorial aggrandizement, of self-glorification in any form. All she wants is gentle peace, sweet friendship, helpful exchange of benefits, and the generous application of that golden rule which people of all nations and all creeds should delight to follow.

CHINESE FOLKLORE AND SOME WESTERN ANALOGIES.

By Frederick Wells Williams.

It is customary in the West to consider the civilization of China as a thing by itself, without relation to the factors which have influenced or evolved our own type of culture. The ways of men at the opposite ends of Asia have diverged widely and long indeed, but we can no longer deny the proofs, if not of their common origin, at least of their frequent intermixture and of their development under substantially similar conditions. With many of these proofs the trained scientist must be left to deal, and it is unlikely that anything save the bare results of his investigations will become popular reading. Almost the only exception to the general truth of this statement is to be found in the study of the myths and legends of these exotic peoples and their comparison with folklore elsewhere. Here, happily, the process is as interesting as the result desired. If we treat patiently the fantastic brood with which primitive man surrounds himself, even humoring a little their eccentricities, we are promised in time a key to their cabalistic lore and an answer to the mystery of man's origin.

Something has already been done to show the connection between customs and superstitions, as well as between languages, in the Indo-European race group. The ghosts and monsters of ancient India and Persia reappearing in classical and mediæval garb in Europe declare again the essential unity of one of the world's great families. It remains to show the remoter but still evident affinity between all the races of man. Such investigations carry us far away in time as well as space. Through the welter of fancies, characterizing the mental processes of primitive and savage peoples seeming to live in their imaginations rather than in a world of material matter, we may trace, perhaps, the dimly remembered forms of antediluvian creatures that continued their existence down to a period when man had to struggle with them for supremacy. An inspection of the fossil remains of mesozoic saurians suggests the familiar dragon common to the mythology of all races alike, and the obvious inference that these supposed flights of imagination were only disordered memories of fierce contests with actual animal enemies long since disappeared. In this sense the contest between Bel and Tiâmat in early Babylonian myth finds its analogue in the encounters with the Chinese Lung, the most popular and persistent monster of Farther Asia. And it is at least a curious fact that the so-called "dragons' bones" sold by apothecaries in China are fossilized teeth. So, too, the sea serpent, the unicorn (the Ki-lin)—adopted as a royal emblem alike by ancient Israel and Japan—the sphinx, and the phœnix are common alike to Europe and China, where they not only assume similar forms, but are ascribed the same supernatural attributes.[1]

Such scattered fragments of information upon this topic as have been collected for this paper serve merely to illustrate the study of Chinese folklore. Much must be learned before it can be placed on a scientific basis.

It will be convenient first of all to contrast the Chinese and Japanese creation myths. According to the Taoist doctrine—which is of all their speculative systems the most characteristically Chinese—in the beginning there was nothingness; then the indefinite produced the definite, or finite chaos, out of which came the yang principle, or light, and following this came yin or darkness. From the alternations of yang and yin, of day and night, were derived all things. The idea is a simple one common to many of the earliest philosophies known. It appears in the ancient cults of Egypt, Babylonia, India, and Persia, and can be fairly referred to the natural promptings of primitive man as he first watched the operations of nature. The dualistic idea thus carried back to the beginning does not of itself imply a common origin for the human race, nor need we consider it as other than self-evident as soon as man begins to think. It ranges through the realm of Chinese metaphysical speculations, but not, as in Persia, to the exclusion of every other guiding principle. It is a similarity less remarkable than that of the triad idea which is also common to Babylonia, Egypt, and China. Thus in the first two nations we have major triads Anu, Ea, and Bel—heaven, the waters, and the earth—and Osiris, Isis, and Horus, eternal elements of the visible universe personified and worshiped; in the latter there is the same elemental division of nature into the "Three Powers," heaven, earth, and man, no one of which is fertile by itself, the union of all three embodying creative force.

The cosmic myth of Taoism which thus establishes man in this supreme company does not, however, intimate that this element of a primeval trinity was anything more than the prototype of the genus homo. "His body," says the document quoted, "was quadrangular in likeness, his face was round, his wisdom and intelligence of heaven's birth. He ever stood erect looking at the four quarters of the great earth, even beholding all beneath to the utmost bounds of the horizon." To this being, thus contemplating the created universe, came down on

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[1] Compare an entertaining and suggestive study of this phase of folklore, entitled "Mythical Monsters," by Charles Gould, London, 1886.

a ray of light the Father of Taoism, a controller of all things, who after looking upon the creature and seeing that he was good explained the laws of nature to him. At the separation of chaos, "the principles of human nature had not been established. Therefore heaven and earth through the instrumentality of the original ether of the dual powers (Yang and Yin), and in their secret conjugal combinations, first produced you, five in number, who are located at the five cardinal points—that is, a being whom I have called Water Sire, the North; the South, styled Red Sire; Wood Sire in the East, and Gold Mother in the West. These all thoroughly understand the abstruse doctrine of renovation. Your disposition being mild and gentle, and your bodily constitution being less agile, you therefore happened to be last of the five that appeared in the world. I have been waiting for you all to enter life; as this has now taken place, I have nothing more to do; I shall therefore depart."

When asked whither he went, the ineffable one replied: "Beyond the circle of water that terminates the universe there is the pure original water, and beyond this there is still the region of perfect nihility, the ether of spontaneousness. When, with an immaterial nature, I enter the region of matter, I assume bodily form; but when I return to that endless void, I lay that form aside and return to my natural state. Do you understand this? Now I will call your four elders to come and assist in performing the wonderful works yet to be done." And saying this the Great Spirit called aloud "with a fearful thundering voice" to each quarter of the heavens, "and then turning, bounded beyond the clouds, and disappeared in a golden halo of light."

To this genius of the earth, representing the center or fifth cardinal point, came in turn the Red, Wood,[1] and Water sires, and while they were conversing "a white mist was seen lying across the horizon, and upon it was Gold Mother walking deliberately. She approached and presented the usual compliments. Each gazed with fixed eye upon her, and noticed the leopard's tail, her tiger teeth, and her disheveled hair. Her head was covered with flowers; a dress adorned with various precious stones was thrown loosely over her shoulder; a long petticoat of mulberry bark was fastened round her waist." This remarkable quintette, after a brief exchange of compliments, proceed at once to the great task for which they are assembled, the creation of man. The earth genius, called Yellow Sire,[2] finds in a cavern the ether pulse and

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[1] Wood Sire is described as tall, slender, and beautiful; his breast is entwined with silken vines and his loins bound with green rattan and leaves sewn with wild hemp. There may be some analogy between him and the Indian Siva, who is closely connected to Dionysus.

[2] Hwang (yellow), "means extensive, liberal, upright, clever, and intelligent. The virtue of hwang harmonizes perfectly to the principles of rectitude; his merits are equal to those of the Great Earth. Such a title well becomes such a personage."

fashions a furnace and kettle; Wood Sire on the East smelts a tripod of the purest of the five metals—gold, silver, brass, iron, and tin; Gold Matron from the West, taking five colored earths, moulds a crucible; Water Sire "opened a precious crystal rock and caught the fresh genii water as it dripped down and put it in the crucible, while Red Sire, facing the South, bored straight into the body of a mulberry tree and obtained fresh genii fire to boil the water with."

Thus the five elders, leaving no detail unattended, "exercised their whole minds and souls, laying aside every other thought, care, and work while perfecting this one; at one time increasing the fire and now diminishing it till the fire had attained its full measure of heat, or nearly so; and on the eighty-first day of the process a beautiful cloud hung over the furnace and the caldron and sweet dew fell on the Seu Mountain. Gold Matron and Wood Sire, preceiving that the refining process was completed, removed the cover and, lo! two little things lay in each other's embrace at the bottom of the dish. Gold Matron put forth her hand and took up one at random and, behold, it was a male child! Wood Sire raised the other and, lo! it was a female infant. Both were exceedingly delighted."

Never was homunculus more carefully conceived or accepted by his creators with greater rejoicing. They all "leaped for joy and mutual delight," it is said, and then, returning each to his habitation, left the children to "imbibe the genial influences of the sun and moon in the grotto till they mutually understood the relations and the mysteries of conjugal life." In time children were born and the earth became peopled with their progeny.

In the Japanese account of creation, related in the sacred scripture of Shinto, called the Kojiki, the formation of the earth—or rather of the Japanese Islands—is immediately followed by the birth of a number of kami, deities imagined after the manner of the gods of Greece as only more powerful human beings. There is no difference apparently in the process by which the divine pair, Izanagi and Izanami, deputed to the task, produce islands and divinities. At length in giving birth to the Fire God, Izanami is burnt and dies. Her spouse forthwith slays the hateful offspring, and then occurs one of the most remarkable episodes in the epos, when he journeys to the underworld, Orpheus-like, to bid his wife return.

"Thereupon his Augustness Izanagi, wishing to meet and see his younger sister [his wife], followed after her to the Land of Hades. So when from the palace she raised the door and came out to meet him, his Augustness Izanagi spoke, saying: 'Thine Augustness, my lovely younger sister! The lands that I and thou made are not yet finished making; so come back!' Then her Augustness Izanami answered, saying: 'Lamentable indeed that thou camest not sooner! I have eaten of the furnace of Hades. Nevertheless, as I reverence the entry here of thine Augustness, my lovely elder brother, I wish to return. Moreover, I will discuss it particularly with the deities of Hades. Look not at me.' Having thus spoken, she went back inside the palace, and as she tarried there very long he could not wait. So having taken and broken off one of the end teeth of the multitudinous and close-toothed comb stuck in the august left bunch of his hair, he lit one light and went in and looked. Maggots were swarming and she was rotting, and in her head dwelt the Great Thunder, and in her breast dwelt the Fire Thunder, and in her belly dwelt the Black Thunder, and in her private parts dwelt the Cleaving Thunder, and in her left hand dwelt the Young Thunder, and in her right hand dwelt the Earth Thunder, and in her left foot dwelt the Rumbling Thunder, and in her right foot dwelt the Couchant Thunder. Altogether eight thunder deities had been born and dwelt there. Hereupon his Augustness Izanagi, overawed at the sight, fled back. Whereupon his younger sister said: 'Thou hast put me to shame,' and at once sent the Ugly Female of Hades to pursue him. So his Augustness Izanagi took his black august headdress and cast it down, and it instantly turned into grapes. While she picked them up and ate them he fled on. But as she still pursued him, he took and broke the multitudinous and close-toothed comb in the right bunch of his hair and cast it down, and it instantly turned into bamboo sprouts. While she pulled them up and ate them, he fled on. Again, later his younger sister sent the eight thunder deities with a thousand and five hundred warriors of Hades to pursue him. So he, drawing the ten-grasp saber that was augustly girded on him, fled forward, brandishing it in his back hand [i. e., behind him], and as they still pursued he took, on reaching the base of the Even Pass of Hades, three peaches that were growing at its base, and waited and smote his pursuers therewith, so that they all fled back. . . . Last of all his younger sister, her Augustness Izanami, came out herself in pursuit. So he drew a thousand-draft rock, and with it blocked up the Even Pass of Hades, and placed the rock in the middle; and they stood opposite to one another and exchanged leave-takings, and her Augustness Izanami said: 'My lovely elder brother, thine Augustness! If thou do like this, I will one day strangle to death a thousand of the folks of thy land.' Then his Augustness Izanagi replied: 'My lovely younger sister, thine Augustness! If thou do this, I will in one day set up a thousand and five hundred parturition houses. In this manner each day a thousand people would surely die, and each day a thousand and five hundred people would surely be born.' So her Augustness Izanami is called the Great Deity of Hades . . ." etc.[1]

Izanagi, though now forever deprived of his helpmeet, manages very creditably by himself to continue the business of creating divinities, who exude from his person while he washes off the pollution of hades, and from whom in time are descended the human inhabitants

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[1] "The Kojiki," translated by B. H. Chamberlain, in Transactions of the Asiatic Society of Japan, Vol. X. Supplement.

of Japan. As a cosmic myth this falls distinctly short of the high conceptions of its Chinese prototype, being cruder, more naive and inconsequential than the other—an imaginative effort of a ruder and less sophisticated folk. Yet its chief value, that of the earliest genuine document of a pure Altaic people, can hardly be exaggerated; and herein lies the charm to Western readers of incidents that, but for some of their grotesque details, might have been taken from the verses of Hesiod or Ovid. Beyond resemblances of the most superficial sort (as in the agency of male and female in creation, in the existence of a Great Spirit before heaven and earth were made) the Chinese and Japanese myths are radically different. The former are for the most part "impassible, passionless, uninteresting," as compared with the fancies developed upon these themes among ancient peoples in the West. Their fundamental idea may be loftier, more philosophical, but their imaginative genius fails in the attempt to personify the operations of nature and endow them with life.

The Japanese tales, on the other hand, abound in instances where human traits and passions are transferred to the powers above, who feel and act in all respects like men of flesh and blood, who are disorderly and irresponsible after the manner of savages, but whose human nature renders them in some vague fashion quite engaging to follow. It is with Greece rather than with China that Japanese mythology must be compared. In both we have the same wayward feeling for impersonation, characteristic alike of children and of primitive races with artistic instincts; the same assemblage of gods in heaven not only caring for but visiting and interfering with mortals; the same material representations of Olympus and Hades; the same gradual withdrawal of personal intercourse between human and divine, as the golden age melts away into the dull prose of recorded history. In neither set of myths is there anything properly corresponding to a religious system, until they become coordinated by philosophers of a later age.

Resemblances between individual episodes in these far-distant collections of primitive folk-tales are less obvious than their general similarity of type. Mention has been already made of the most striking parallel, that of Izanagi's descent into the lower world to redeem his wife, and Orpheus's expedition for the same purpose. To find a fitting analogy to the withdrawal of Ama Terasu, the Sun Goddess, from the heavens, we should go to an older mythology, that of Babylonia, where, in Ishtar's search for her lover Tammuz in hell, all nature suffers and is dead until her return—clearly a story symbolizing the torpor of vegetable life in winter and its return to vigor in spring. The Japanese tale runs as follows: A brother of the Sun Goddess having exhausted her patience by a long career of crime and insult, finally caps the climax of his misdeeds by breaking a hole in the top of her "awful weaving hall," where she sat with her fourscore maidens weaving the august garments of the deities, and throwing upon the frightened group "a heavenly piebald horse, which he had flayed with a backward flaying." The Goddess then closed fast the portal of her heavenly rock dwelling, and all the world became dark and "the voices of the myriad deities were like unto the flies in the fifth moon as they swarmed, and a myriad portents of woe all arose." When the crowd was assembled about the closed door, the Goddess of Mirth performed a dance with a mirror, while eight hundred myriad deities laughed together, and the plain of high heaven shook with the noise. Opening the door a little, the Sun Goddess inquired why the company rejoiced when the world was wrapped in gloom because of her absence. "We are glad," they answered, "because there is a deity more brilliant than thine Augustness;" and when a pardonable jealousy made her come forth to see her own fair face in the mirror, they cleverly pushed the door to behind her, and the earth was once more bathed in light.

It is easy to exclaim against this rather unkind reflection upon feminine weakness and vanity, that the legend was fabricated when coarse and cruel man ruled society by sheer brute strength. Yet this criticism, if made, would be far from just or true. The incident really exhibits the utter inability of the combined heavenly host to compel one of its female members to return to their society. After their successful ruse they concede her superiority by giving her precedence over all other divinities of heaven, a supremacy which she has always enjoyed in the hearts of the Japanese people. In the same manner the authority of her sex is exhibited in Ama Terasu's punishment of her brother, the Moon God, by forbidding him to appear in her company because of brutal and tyrannical conduct toward earth's inhabitants on a melancholy occasion. The instinctive love of woman's tenderness and the idealization which goes with our appreciation of her gentleness and grace have made their impress everywhere upon the religions as well as the folk-tales of the world. The adoration of the Virgin Mary among Christians, of Tien Hou Mang among Taoists, and of Kwan Yin, Goddess of Mercy, among the Buddhists of China and Japan, are instances of the same fundamental idea developed in more complex institutions; nor will it be denied that reverence for the Ewig Weibliche thus embodied is a true feeling, a right and natural craving.

It is proper to emphasize this nobler attitude toward the weaker sex manifested in the earlier civilization of the East, because we are too often led by the customs prevailing there to-day to conclude that the Asiatic has ever been regardless of woman's rights. A great store of anecdotes might be adduced to establish a contrary conclusion. One must be allowed here to typify the admiration excited by unselfish and courageous acts of women—an admiration as spontaneously enkindled in the East as among ourselves when the achievement is really deserving. The heroine of this incident is supposed to have lived in China during the reign of the Emperor Yung-loh, early in the fifteenth century of our era, but the story seems to owe its birth to a much older tradition. The father of Ko-ai, having been ordered to cast a huge bell of bronze, had failed twice in the very difficult task, the metal having "honeycombed" in each attempt. Yung-loh, being thoroughly enraged at the double failure, promised the founder that he would behead him if the third trial did not prove successful. Then it was that the girl of 16 showed the metal in her in more senses than one. Taking counsel of a master astrologer, she learned that the only means of averting calamity and insuring a perfect casting was that of mixing a virgin's blood in the molten stream as it filled the mold. To save her father's life, therefore, she plunged headlong into the liquid mass as the third casting was being made, and all that remained of her was the shoe which a workman had grasped and pulled off her foot in frantic effort to prevent her sudden plunge. The wretched father was carried home a raving maniac; but the astrologer must have known his business, for was not the bell a perfect success, as anyone may prove to-day by going to Pekin and listening to its sonorous boom? Only every stroke is followed by a low, wailing cry that seems to reverberate the word hsieh (shoe) in fainter and fainter tones until all is still. That, they say, is poor Ko-ai calling for her lost shoe.

This pathetic legend might perhaps be duplicated in more than one literature of eastern and western romancers. A still more widely diffused genus of folk-tale, based upon the evanescent charm of womanhood, is discovered in the so-called "Swan-Maiden" group. The type of this group appears clearly in the far north of Asia, where among the Samoyeds the tale, shorn of its adornments, runs somewhat as follows: A hunter coming upon an old woman chopping birch trees stopped and helped her cut and carry the logs to her hut. Highly gratified at this attention she bade him hide there and see what would happen. Presently seven beautiful girls came in, asked if anyone was about, and being told that the woman was quite alone, took their way to a neighboring lake where they went in swimming. The man followed them, and at the suggestion of his aged hostess, stole one of the feather dresses left on the shore by the maidens. Of course, when they emerged one hapless girl was unable to find her costume and could not fly away with her companions. She begged the hunter to restore her clothes "because she was freezing," and even promised if he did to become his wife; but he does not yield until she consents to secure for him the hearts of some villains who have slain his mother. She does so, and the story then rambles on in a wilderness of inventions which need not concern us. Among the Tartars the swan-women are grim and evil-hearted creatures, sometimes darkening the whole sky with their raven wings, and again lapping the blood of the slain, while in the Shetland Islands a similar myth brings the women to the bathing beach in the guise of seals.

The feather-dress *motif* reappears in western Asia, with abundant adornment, in the Arabian Nights Entertainments, as a basis of the "Story of Hasan of el-Basrah." Here the hero, while idling in a wonderful garden, beheld ten great birds, among them one more beautiful than the rest, alight; and as he concealed himself to watch at greater advantage "they seated themselves upon the couch, and each of them rent open its skin with its talons and came forth from it, and lo, it was a dress of feathers. There came from the dresses ten damsels, virgins, who shamed by their beauty the luster of the moon; and when they had divested themselves, they all descended into the pool and washed, and proceeded to play and to jest together, the bird who surpassed the others throwing them down and plunging them, and they fleeing from her and unable to put forth their hands to her." Hasan becomes violently enamored, but is unable to detain them until, on a subsequent visit, he is told to secure the dress of the leader. The girl is wild with terror at first, but eventually turns into a pretty good wife and becomes the mother of two boys. The dress of feathers is not destroyed, however, and during her husband's absence from home she secures it by a ruse from his old mother and instantly flies off in it with her children to the Islands of Wak-Wak. These islands, from which Hasan eventually regains his wife, are supposed by commentators to be either Japan or the Sunda islands, and it has been reasonably suggested that their name is derived from the cry "Wok-Wok" of the great Bird of Paradise which abounds there. A similar encounter with bird-women occurs also in the Arabic romance of Seyf-Zu-l-Yezin.[1]

Returning now to eastern Asia we again meet, in the islands of Lew Chew, a member of the mysterious company, who is as beautiful as her sisters of Siberia. A respectable young man—goes the story as related by a Chinese envoy to Lew Chew—was scandalized to find a female bathing in his spring. After the old, old fashion, which boys the world over know, he sought her clothes on a neighboring bush, but was amazed to find as he confiscated them that they were of gossamer, ruddy and gay with sunset hues, altogether unlike any dame's dress he had ever seen. The young woman, finishing her plunge, discovered her loss and threw herself on the ground before him begging for her garments; but he was obdurate and insisted upon her remaining with him. At the end of ten years of married life, during which she bore him two children, her fate was fulfilled and she drifted away one day on a fleecy cloud. In one of the German variants of the myth most closely approaching this version, the huntsman who has secured his

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[1] Lane's Arabian Nights, Vol. III, chap. xxv. C. Gould's Mythical Monsters, p. 140.

swan-wife keeps her plumes in a cupboard for fifteen years, but one day forgets to lock it, when the captive dons them in his absence and spreads her wings never to return—a variant of the Arabian romance.

Without delaying here to dwell upon the infinite permutations of this theme in Hindu, Persian, Arab, Greek, Celtic, Teutonic, Scandinavian, and other mythologies, we can not dismiss it finally without alluding to the guise which it assumes in Japan. Here the damsel is called the Moon Maiden, and she is a musician as well as a dream of beauty as she drifts down from the evening sky beyond Fuji to bathe in the shimmering sea. A fisher boy sees her fragile feather robe gleaming from a pine tree, takes it, and is soon confronted with the owner who begs its return. He asks to see her dance before he grants her request, but "I can not dance without my robe," she says. "Each feather has been given me by the Heavenly Birds. Their love and trust support me." Then the lad cries forgiveness for his rudeness and returns the robe. Her dance begins with merry step and cadence along the shore, rustling over the grass, under the blossoming cherry, and in and out among the trees. But gradually she floats farther and farther away toward the distant mountain and the fisherman is left alone by the sea. Is it too extravagant an hypothesis to see in this idyl of floating cloud-forms that drift from heaven to dip at times in sea and lake, that keep company with the birds but dissolve away at touch of man, the germ of the Vedic Apsaras of our angels—"who were but the fleecy clouds, supposed in the ages of man's simplicity to be celestial swans?"[1]

Since we have found ample illustration of the evident affiliation of Aryan and Turanian myths in these instances of devotion to woman, it will not be thought ungenerous, perhaps, to adduce a famous case of inconstancy which exemplifies the same conformity. The story in its Chinese version is related of a Taoist philosopher who was a contemporary of Alexander the Great. The elements of sheer witchcraft and characteristic human nature commingle in a grotesque fashion especially pleasing to followers of the doctrine of Tao, or Rationalism, in China. The basis of the tale is thought to be an importation from India, the fatherland of the world's best fables and fictions, but we will hear it first in a translation of a Chinese ballad entitled

FANNING THE GRAVE.

'Twas spring, the air was redolent
With many a sweet and grateful scent;
The peach and plum bloomed side by side,
Like blushing maid and pale-faced bride;
Coy willows stealthily were seen
Opening their eyes of living green,
As if to watch the sturdy strife
Of nature struggling into life.

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[1] Baring-Gould, "Curious Myths," p. 578.

One sunny morning Mr. Chwang
Was strolling leisurely along,
Viewing the budding flowers and trees,
Sniffing the fragrance-laden breeze,
Staring at those who hurried by,
Each loaded with a good supply
Of imitation sycee shoes,
To burn—for friends defunct to use—
Of dainty viands, oil and rice
And wine to pour in sacrifice
On tombs of friends who 'neath them slept.
'Twas "third of the third" when graves are swept.

Chwang sauntered on; at length, on looking round,
He spied a cozy-looking burial ground;
"I'll turn in here and rest a bit," thought he,
"And muse a while on life's uncertainty;
This quiet place just suits my pensive mood,
I'll sit and moralize in pleasant solitude."
So, sitting down upon a grassy knoll,
He sighed; when all at once upon him stole
A smothered sound of sorrow and distress,
As if one wept in very bitterness.

Mr. Chwang, hearing this, at once got up to see
Who the sorrowing mourner could possibly be,
  When he saw a young woman fanning a grave.
Her three-inch gold lilies were bandaged up tight
In the deepest of mourning; her clothes, too, were white.
Of all the strange things he had read of or heard,
This one was by far the most strange and absurd;
  He had never heard tell of one fanning a grave.

He stood looking on at this queer scene of woe
Unobserved, but astonished, and curious to know
  The reason the woman was fanning the grave.
He thought, in this case, the best thing he could do
Was to ask her himself; so without more ado,
He hemmed once or twice, then bowing his head,
Advanced to the woman and smilingly said:
  "May I ask, madam, why you are fanning that grave?"

The woman, on this, glancing up with surprise,
Looked as tho' she could scarcely believe her own eyes
  When she saw a man watching her fanning the grave.
He was handsome, and might have been thirty or more;
The garb of a Taoist he tastefully wore;
His kind manner soon put her quite at her ease,
So she answered demurely, "Listen, sir, if you please,
  And I'll tell you the reason I'm fanning this grave.

"My husband, alas! whom I now (sob, sob) mourn,
A short time since (sob) to this grave (sob) was borne;
  And (sob) he lies buried in this (sob, sob) grave.
(Here she bitterly wept.) Ere my (sob) husband died,
He called me (sob) once (sob, sob) to his side,
And grasping my (sob)—with his dying lips said,
'When I'm gone (sob, sob) promise (sob) never to wed
  Till the mold is (sob) dry on the top of my grave.'

"I come hither daily to (sob) and to weep,
For the promise I gave (sob) I'll faithfully keep,
  I'll not wed till the mold is (sob) dry on his grave.
I don't want to marry again (sob), I'm sure,
But poverty (sob) is so hard to endure,
And, oh! I'm so lonely, that I come (sob) to try
If I can't with my fan help the damp mold to dry,
  And that is the reason I'm fanning the grave."

Hearing this, Chwang exclaimed, "Madam, give me the fan.
I'll willingly help you as much as I can
  In drying the mold on your poor husband's grave."
She readily handed the fan up to Chwang,
(Who in magic was skilled, as he proved before long),
For he muttered some words in a low undertone,
Flicked the fan, and the grave was as dry as a bone;
  "There," said he, "the mold's dry on the top of the grave."

Joy plainly was seen on the poor woman's face
As she hastily thanked him, ere quitting the place,
  For helping her dry up the mold on the grave.
Chwang watched her go off with a cynical sigh;
Thought he, "Now suppose I myself were to die,
How long would *my* wife in her weeds mourn my fate?
Would she, like this woman, have patience to wait
  Till the mold was well dry on her poor husband's grave?"[1]

The philosopher, upon his return home, relates the adventure to his wife, and she is so violent in her denunciation of the faithless widow that he resolves to test her. Soon he falls ill and dies; and while the celebrated savant lies encoffined in his hall many come to do him reverence and try to console the stricken woman. Among the number is a handsome young man, a former pupil of the master, who makes himself so attractive as to win her heart and hand during the short period of his visit. While rejoicing in her rediscovered bliss, the woman's newly affianced falls into convulsions, the only remedy for which is human brains, fresh, boiled in wine. The case is pressing; there lies the unburied corpse of her former spouse, now useless to her, unless, indeed, she can apply his brains to restore her present lover to health and even to life. So she seizes an axe, chops open the coffin, and, behold, her old Chwang rises alive and well! He had been playing with his wife, and actually assumed the form of the young scholar himself to test the constancy of her affection. Unable to conceal her shame, the wretched woman hung herself with her own girdle, while the disgusted Chwang, burning his house, withdrew from the world.

A Semitic story of the Wife Tested has a different setting, but descends evidently from the same parent stock. In this the learned and Beautiful Berurya, while reading an ancient text, comes upon the sentence, "All women are fickle," and appends the marginal gloss, "Except Berurya." Her husband, Rabbi Meïr, the Light of the Law,

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[1] G. C. Stent, "The Jade Chaplet."

finding the note, comments: "You will yourself some day prove the truth of this saying." He introduces, in course of time, a handsome young disciple, who courts Berurya assiduously, and finally obtains her consent to an assignation. But when she keeps it the master appears instead of the pupil, and Berurya, finding her infamy discovered, goes out and hangs herself.

Even nearer to its far-eastern original than this harsh Talmudic legend comes the famous tale of Petronius, who lived under the Emperor Nero. The "Matron of Ephesus" is a woman who was so inconsolable after her husband's death that she could not bear to leave the grave, but watched and wept there while a trusty maid brought her provisions. It so happened that hard by the cemetery lay an execution ground where a young soldier was stationed to watch the bodies of some crucified malefactors. Hearing a sound of sobbing he was touched to find a pretty widow in so unusual a situation, and brought his wallet to share with her. She would none of him or his food at first, but presently she succumbed to the fascination of such an unusually handsome fellow, and the pair spent three days and nights very comfortably together in the tomb. Then the soldier discovered that the body of one of the malefactors on the cross had disappeared, and was about to forestall the inevitable punishment due to his remissness by committing suicide on the spot, when the widow bade him stay his hand and hang the corpse of her husband on the cross and thereby conceal his dereliction: "For," she exclaimed, "I could not bear to have the only two men I ever loved lying dead at once before me!" In this guise the story begins its migrations throughout ancient and mediæval Europe, appearing, with innumerable modifications, of course, in the literatures of France, Italy, Spain, Russia, England, and Germany. In England, besides being the theme of many early plays, it is charmingly told in Goldsmith's Citizen of the World, while in France it becomes the plot of Voltaire's Zadig.

We are hardly prepared, after tracing the perigrinations of this unmerited satire on woman's constancy, to learn that in the land of its origin a slip of a girl is the true hero of our legendary "George and the Dragon." In the Yung Ling Mountains of eastern China there dwelt a dragon 80 feet long and 10 feet round. His diet consisted by choice of likely little girls not more than 13 years old, and upon condition of receiving these he consented to spare the neighborhood from indiscriminate ravage. In the course of years the supply of virgins, bond servants, and daughters of criminals gave out, and the governor of the country was in sore straits, when the youngest of his six daughters offered herself as a sacrifice. She argued that a sixth girl in a family wasn't worth her keep, so despite all opposition she proceeded to the fatal cavern, asking only a sword, a good dog, and plenty of boiled rice. Mixing the food with honey she placed it in the narrow mouth of the cave, and when the dragon was breaking his fast upon this hors d'œuvre, the dog attacked him with his teeth while little Ki hacked away from behind so that the monster died. On hearing of this mighty deed we are glad to learn that the Prince of Sueh asked her hand in marriage and raised her to his throne. Here is an almost perfect analogue to the Vedic Indra and Ahi, the Iranian Mithra and Ahriman, the Greek Perseus and Andromeda, the British Beowulf and Grendel, the Teutonic Siegfried, and a host of others.

To the student of Chinese folklore the special interest of Taoist literature lies in the fact that, though dating from only the sixth century B. C., as a philosophical system, this so-called religion is based upon and includes the oldest myths and legends indigenous to eastern Asia. The popular success of Laotsz's doctrine and its permanence in Chinese culture may be quite confidently ascribed to its acceptance of folklore creations handed down from primitive man in Asia, for the acknowledged creed of every race, even the most advanced, has ever been influenced by assimilating more or less unconsciously the ideas with which its adherents were most deeply imbued. To take an instance that occurs instantly to the mind: It was not the wish of Buddha or of Christ to countenance the worship of images; on the contrary, both preached against their use; but the great mass of those who profess and call themselves followers of their teachings have in all ages bowed down to wood and stone. The head of the idol, indeed, may be of refined gold, and its purpose in the sanctuary explained esoterically, but its feet are of clay—the soil upon which the lowly mass of worshipers lived and worked and wondered for centuries before they heard the incarnate word promulgated.

With Laotsz, the philosopher of rationalism, we need therefore have no concern here, but with the cult which has assumed the name of Tao, though in practice utterly indifferent to the high purpose of his abstruse doctrine, we are intimately involved as soon as we begin to penetrate the current faiths and fancies of the Chinese people.

It is in the writings of the earlier Taoist disciples that the fairy mythology of primitive China first takes literary shape. One of them, Chwang-cheu, after meditating long enough on nature to think that nature was identical with himself, gave utterance to a doubt that has been familiar in many guises to modern Western philosophers. "For when I dream I am a butterfly," he declared, "it is not for me to say that the dream is my own, or whether it is a butterfly dreaming that he is Chwang-cheu." Another, Lie-tsz, who wrote in the middle of the fifth century B. C., describes the fairy islands of the eastern ocean, "beyond the Pihai, at a distance of I know not how many hundreds of thousands of li, where are five islands, each 30,000 li in circuit, and lying 70,000 li apart. This distance is not supposed to be too great for them to regard each other as neighbors. The towers and other lofty buildings are of gold and jade. The birds and beasts are beautiful in form and color. The trees look like columns of pearl. The fruits have a delightful taste, and those who eat of them never grow old or die. The inhabitants are men who belong to the class of the immortals and are all sages. In one day and night they fly to the other isles and back again. The five islands are quite separate at their base and float on the ocean surface as the tide and waves compel them in unresisting movement,"[1] etc.

Change the points of the compass and we have in this ancient chronicle a sufficient description of that group of islands across the boundless ocean that occurs in every ancient literature of the West. Atlantis, the Hesperides, remote Ogygia, and the Celtish Avalon, of Arthurian legend,

> Where falls not hail, or rain, or any snow,
> Nor ever wind blows loudly; but lies
> Deep-meadow'd, happy, fair, with orchard lawns
> And bowery hollows crowned with summer sea,

are all prototypes of these far-away isles. The belief in Europe in this mysterious land is prevalent in Norse, Teutonic, and Celtic, as well as in Greek and Egyptian folklore, and many tales of singular beauty are woven upon this theme. In each land these distant isles take color from the fancies and prejudices of the people who portray their imaginary delights, but like pictures of heaven—with which indeed they unwittingly blend—they are much alike in feeling if not in detail. It became the fashion in the twelfth century to burlesque the notion. A French poem calls it cookeryland, Cocaigne, where run rivers of wine and roasted geese go down the street turning themselves until they are done perfectly brown; where the ladies are always fair and have new clothes every month; where the fountain of perpetual youth washes off weakness and age and renews the appetite and enthusiasm of its favored inhabitants. The Portuguese version of the old myth, as related by Washington Irving,[2] shows it adapted to the preferences of a Christian people. Once upon a time, this story runs, an old pilot was blown ashore near Lisbon, raving about an island far beyond the Canaries upon which he had been driven and where he had found a gracious company descended from certain of his countrymen who had escaped thither when Spain was conquered by the Moslems. They were recognized, when he told his tale, as the band of Christian exiles who had indeed fled from the Moors under seven bishops, and whose fate had hitherto remained a mystery. The ardent young cavalier, Don Fernando de Alma, soon gathered a company to search for the mysterious island, and after driving about tempestuous seas for many days his caravel found itself, when the storm lifted, in

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[1] J. Edkins: "Steps in the Growth of Early Taoism," Chin. Recorder, May, 1884.

[2] Chronicles of Wolfert's Roost, and other Papers.

a pleasant harbor, beyond which could be seen the towers and castles of a noble city. The adventurer left his companions in the stately barge that came out to meet him, and was entertained one evening at the court-house of an old-time city, where everything bespoke the fashions and manners of three centuries ago. Taken back to the harbor he found no caravel there, but when he awoke from the slumber into which the rowers' chant had lulled him he learned that he had been picked up senseless from a drifting wreck by a passing Portuguese trader. Arriving at his ancestral home he found that his family had long since departed. More fortunate in seeking the house of his betrothed, he espied her upon a balcony, and was about to spring into her arms when she sought protection from a young cavalier by her side. She was not his ladylove, but the great-granddaughter of the Serafina Alvarez whom Don Fernando had left when he set out upon his strange voyage.

Nor are the Japanese without their islands of perpetual youth, where time passes unnoted by the blissful inhabitants, after the fashion in which aging humanity has essayed to portray them since the days long ago when men first began to grow old. The land of Horaizan, where reigns eternal spring, where ethereal blossoms ever bloom upon the fertile slopes of Fusan, the Mountain of Immortality, where pain and sorrow are unknown, lies far away in the eastern sea. Once, it is said, the physician of a cruel Chinese tyrant escaped the despot's clutches by promising to pick for his master the herb of immortality from this favored shore; but he never came back, and nothing would have been known of his success had it not been for Wasobiowe, a wise man of Japan, who was driven over the ocean by a hurricane, and found him, heedless of his errand, and living a joyous life among the elect of the gods in that deathless abode. Wasobiowe lived several hundred years agreeably enough in these delectable surroundings, but, being Japanese, he wearied at length even of heavenly content, and was brought home on the back of a stork to die in his beloved Nagasaki.

It seems hardly possible that mere accidental similarity can sufficiently explain that prevalent fancy of a lost Atlantis in Europe, that large island situated many days' sail from Libya toward the west, which, in the description of Diodorus Siculus, "abounds with gardens stored with various trees and numerous orchards intersected by pleasant streams, * * * excelling so much in felicity as to resemble the habitations of gods rather than of men."[1]

No feature is perhaps more common to the folk legends of Europe and Asia than the magical passage of time in slumber or in a visit to some place of enchantment. The germ of this notion has been referred with some plausibility to the long sleep of nature during winter, after

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[1] The late Ignatius Donnelly made much of this tradition in his fanciful "Atlantis," New York, 1882.

which the earth seems to renew her normal functions as though unconscious of her prolonged repose. Various phases of the idea present themselves, ranging from the three hundred and sixty years' repose of the Seven Sleepers of Ephesus to the supposed death-like torpor of great heroes like Charlemagne, Barbarossa, and Jengiz Khan, whose slumber, though still unbroken, is some day to terminate when they arise and lead their people to new victories. A Christianized form of the myth occurs in the mediæval legend of a monk, who, wondering how the Psalmist's "thousand years of the Lord" could be as one day, went forth into the woods to meditate upon the mystery. There he heard a bird singing with such ineffable sweetness as to keep him spellbound all the afternoon; but when he returned to his monastery he discovered after some perplexing experiences that he had remained listening to God's tuneful messenger a thousand years, which had passed as one day.

What we may term the Rip Van Winkle type of story is closely paralleled in the Taoist legend of Wang Chih, a patriarch of the sect. "Wandering one day in the mountains of Küchow to gather firewood, he entered a grotto in which some aged men were seated intent upon a game of chess. He laid down his ax and looked on at their game, in the course of which one of the old men handed him a thing in shape and size like a date stone, telling him to put it into his mouth. No sooner had he tasted it than he became oblivious of hunger and thirst. After some time had elapsed one of the players said: 'It is long since you came here; you should go home now.' Whereupon Wang Chih proceeding to pick up his ax found that its handle had moldered into dust. On repairing to his home he discovered that centuries had passed since the time when he had left it for the mountains, and that no vestige of his kinsfolk remained. Retiring to a retreat among the hills, he devoted himself to the rites of Taoism, and finally attained immortality"[1]—a conclusion only differing in degree from that of Rip's adventure, whose immortality is of another sort.

Another similar legend—a favorite of Chinese story-tellers—makes the experience befall two young men while gathering herbs among the hills. Here they discover a fairy bridge in charge of two maidens, who are as charming as they subsequently prove to be complaisant. The girls invite them to cross to the land of pure delight beyond the bridge, and after a summer day's enjoyment of the enchanted land and its people they return to find that seven generations have been born and passed away since their little holiday excursion, and that they are centenarians. The introduction of the magic bridge in this account reminds us of another feature familiar to Teutonic mythology—the bridge connecting the celestial city with the earth, the final crossing of which, in the Götterdämmerung, completes the heroic cycle of the Nibelungen lay. In each case the obvious origin of the conceit is to be

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[1] Dennys, Folk Lore of China, 98.

found in the rainbow, as in all probability is the magic arch or causeway joining heaven and earth, upon which the Japanese creative pair Izanagi and Izanami stand to dip their divine wand into the ocean and form the first island out of the drops dripping from its point.

Apropos of Japan, we discover in her fairy tales many developments of the oft-repeated theme of the unconscious flight of time already alluded to. Wang Chih's experience in watching the chess players is repeated in that of Lu Wen, a Japanese woodcutter, with an exactness that proves the Chinese origin of the story. The same motif inspires the popular tale of the fisher boy of Urashima, an adventure ascribed to the period of the Empress Suiko, in the seventh century of our era. In this account Tarō, the dutiful son of poor parents, after praying to the sea god in a storm, is rewarded by the appearance of a kindly old divinity upon a tortoise, who bids him mount up beside him and all will be well. He is taken to a palace of magnificent proportions and populous with radiant throngs, who, with the naïve egotism ever characterizing dreams and fairy tales, unite to do him honor. Here the ingenuous Tarō spent seven blissful days; but being as good as he was happy, he at length asked permission to return to his father. A box was given him, as he remounted the tortoise, with injunctions never to open it. Arrived at the familiar seabeach, he found the inhabitants and their dwellings entirely changed, and learned presently that his family had been dead and buried twelve generations before. Of course he opens the box, a purple mist arises, envelops him, and he sinks down to die of the weight and infirmities of four hundred years thus suddenly acquired.

A considerable group of anecdotes might be collected throughout the East resembling the "Judgment of Solomon." Here are three from China, the first introducing a bit of the supernatural element extremely characteristic of popular stories there: A thousand years ago or less there lived a young man and his charming bride, whose love and happiness were enough to excite the jealousy of a white dog. The brute therefore turned himself into a replica of the husband, and was enjoying the success of his deception when the real spouse returned. Each began to accuse the other of fraud, and the poor wife, being quite unable to decide between them, made both come with her to a magistrate. The officer, with the politician's fine sense of sorcery, suspecting a dog in disguise, put both the fellows into the cage of a tame tiger, whose special aversion was dogs. Of course the sagacious animal knew which was the false husband and the real canine, and the affectionate couple were reunited.

The second variant of the theme relates to the wife of a man who was so long separated from him that, believing her husband dead, she married another. Unlike Enoch Arden, the man on his return wants his wife back, while her second spouse denies any prior lien upon his property which he is bound to respect. The woman herself, being attached to both and unable to decide as to which has the better claim, brings the case to the local magistrate, who orders the suppliant to be confined in a cell over night. On the morrow the rival husbands look into the room where she was placed, to find her body hanging from the rafters. Suicide, it may be observed here, is so common in China as hardly to occasion a remark in passing. The judge, after this discovery, asks who will give the poor sacrifice to their jealous loves a decent burial. The second husband declares that he was contending for a live mate, not a dead one; the first, however, takes it upon himself to perform the last sad rites in honor of his beloved, when she is brought in and given to him alive and well. A straw figure had been dressed in her clothes and suspended in her cell by the wily magistrate to test the real sentiments of the two men.

A third resembles the Bible story in all but its brutal Semitic denouement. Two women had each a boy, but upon the death of one infant his mother claims the surviving child. When the case is brought before the justice he orders one of his domestics to take the lad and train him for official life. As he supposed, the pretended mother demurs, being only desirous of having the child herself; but the real mother, glad of such an opportunity for her offspring, tearfully consents to losing him provided his future is secured. There is, we must confess, a finer sentiment about this version than pertains to either the Hebrew rendition or its Japanese analogue, in which latter the famous Judge Okā orders each claimant to pull an arm of the child until it leaves its socket. Naturally only one shoulder is dislocated in the process, and the true parent is thereby discovered. To the Chinese belongs the credit of telling this famous old story without hurt or even threat of mischief to the child.[1]

When Emerson declared that "the highest can not be spoken of in words" he intended no allusion to Polynesia and the Far East, but his apothegm conveys perfectly the idea embodied in their widespread practice of euphemism and tabu. The word tabu (tapu) has become too familiar to need explanation in any modern European language; yet the institution with all its dread force has never perhaps been adequately understood in the West. Doubtless in its original inception it belongs to primitive man, and when the old Persian monarchs punished contumacious officials by condemning them to stand in the open court by the palace gate, where it was death to feed or touch them, but where the guard compelled them to remain until they starved, they simply perpetuated a practice of their remote ancestors. No custom, indeed, is more universal. For instance, the Tahitians will never use the house or personal belongings of the dead. In ancient Japan a new

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[1] Compare also a Cambodian version of the same theme by A. Leclère, Révue de l'histoire des religions (Musée Guimet) 19e année 7. 38. No. 2. Sept.-Oct. 1899, p.176.

palace had to be built for each new emperor, some distance from the establishment of his deceased predecessor. Nor is it unlikely that the barbaric Asiatic and African custom of killing and burying all a dead king's wives, servants, and horses was simply an enforcement of the tabu that involved them all in the category of his personal effects. In China, as in ancient western Asia, the institution applies chiefly to expressions rather than to acts. Thus the Emperor's proper name is not permitted to be written or pronounced by any of his subjects, the characters being amended and their sounds changed when his reign begins. Confucius's personal name, K'iu, must never be used. When it occurs in the writings of his commentators it is pronounced mau, and this has always been so. In time even the conventional mau has acquired a sort of veneration that unfits it for vulgar use, so that an acre of land—which happens to be the meaning of mau—is called "yau" in South China. Now, by a whimsical coincidence, yau is the Canton pronunciation for the unpronounceable name (K'iu) itself. Thus it happens that the original tabued word has replaced the one which was first adopted to replace the original.

All this will suggest to the Bible student the sanctity that made the name Yahweh unutterable among the Jews, whose Talmudic legends also declare that Solomon made heaven and earth to quake when he uttered the uncommunicable name. It must have been some naïve dread of offending their deities that led other ancient peoples, including the Greeks, to coin attributive titles instead of calling them by name. It is the same kind of respect that a Kirghiz woman to-day shows her husband, whose real name she never permits herself to utter in the presence of others. A Chinaman for the same reason will not say his father's or grandfather's names whether they be alive or dead. In this manner, and through extension of the notion of tabu, has arisen the practice of euphemism, which is so common as to be a heritage of all mankind. If the word or idea is offensive another must take its place, as among the Jews, being forbidden swine's flesh, they called the pig "the other thing." Death and diseases naturally come in for the larger share of these, some of the Chinese expressions being quaintly suggestive, as when a funeral is referred to as "that white affair," or the chills as "buying firewood illness." The source of this euphemistic habit—fear of irritating the lurking demon—must account for the peculiar Chinese usage of either giving their sons girls' names, or dubbing them "little pig" or "black cur," and similar ungentle appellations, that the divinities may be deceived into thinking their possessors unimportant. We may forgive them the implied reflection upon the sex, for the hateful deity in question is supposed to have no appetite for little girls, therefore the exchange of names does no harm. The pathetic efforts of Asiatic parents to outwit the dread monster who would rob them of their offspring are grotesque enough, but they reflect a feeling that stirs the heart of all mankind. A grandmother in Canton with some ostentation weighs the tiny boy who has just arrived to cheer his parents after the loss of their firstborn—the hope being that the waiting god may pass him by because of his insignificance. A mother in England had three daughters in succession named Helen, and all died. When a near neighbor, whose second daughter, called Marian because she resembled her dead sister of that name, fell dangerously ill, remembered the fate of the other family and substituted Maude for Marian, the girl recovered and few doubted that the timely tabu had removed the spell. Is there much difference between the pagan and the Christian episode?

The horrid sprite who feeds chiefly upon infants of tender years is a female ogre, called in Canton Sam-ku-lok-po. She bears a strong affinity to the Lilith of Rabbinical legends—that earthborn first spouse of father Adam, who was turned into a demon that has vexed his progeny ever since the fall—herself merely a later semitic version of the proto Babylonian Lillal and Kiel-lillal, male and female devils of the night. She it is who enters the children when they have long crying spells or when their souls are wandering (as souls will always wander) in sleep. The changeling thus engendered must be promptly dealt with or all is lost and the child grows up an idiot. An ink of dried banana-peel ash and water should be made and a cross marked on the baby's forehead the next time he is asleep. Then when Sam-ku-lok-po swoops down again on obscene wing she will fail to recognize her victim and the little soul can creep back once more.[1] This is a less offensive mummery than the Irish test of putting the suspected changeling on a shovel and holding him over a muck heap. But what shall we say of the sign of the cross in Chinese folk-cult; is it accident or survival?

While considering this phase of our subject we are irresistably led to the matter of demonology and witchcraft, without some regard for which no discussion of folk-lore would be complete. The air of the Eastern world is peopled, as everyone knows, with jinns and spirits both good and evil, while in China reliable accounts of their confederates and interpreters, the wizards, go back at least as far as thirteen centuries before Christ. The communication of human beings with these powers is not looked upon there with the sort of horror it has always inspired in the West. The uneducated look with some qualms upon those versed in the magic arts, while the lettered sneer at their pretensions, but there is no notion on the part of either element of society to prohibit or persecute. In ancient days the office of wizard in chief, the efficient agent of all the occult powers that might injure or influence the realm, was as considerable an appointment at the court of China as of Persia. The love of genii in the East resembles so closely that in the west of Asia as to call for no particular notice to anyone acquainted with the Arabian

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[1] China Review, Vol. IX, p. 204.

Nights Entertainments. Jinns can become small or large, visible or invisible, live in air, water, or earth, without breathing or eating, assume any shape, and control any number of assistants. Taoists ascribe to them immortality, and consider them as the highest order of intelligent beings, but there seems to be some uncertainty as to the distinction between genii and shên or spirits, a lower order of immaterial beings recognized in their mythology. They form an indispensable element in tales of all sorts, being regarded for the most part as rather helpful and gracious powers, though often extremely dangerous to deal with. In the romance entitled The Thunder Peak Pagoda, recently paraphrased in Julian Ralph's charming little volume Alone in China, the heroine is a snake jinn, who transforms herself into a beautiful woman and wins the love of an honorable man. She procures money by the simple process of sending her serpent attendant to filch it from any and every part of the empire. Yet, though she brings trouble and disgrace upon her husband, she begets a son who makes the family famous, and eventually obtains forgiveness and reunion in the spirit world with the man who loved her.

Another romantic experience of a similar, though happier, kind is related in the story of the Enchanted Peonies, wherein a gentleman living in a monastery among the hills becomes enamoured of one of two flower fays. After some months of pleasant companionship she disappears, because her peony bush is uprooted. The disconsolate lover at length learns through her companion spirit that the god of the spirit world, in commisseration for their woes, has consented to restore her to a flower in the monastery. She presently reappears, and at the end of a long life together both lover and mistress are united in the form of flower fays.

Disembodied spirits, in Chinese folk-lore, are endowed with strange powers when they return to earth, and are occasionally permitted to employ them in earning freedom from repeated births, thereby becoming at once angels in a state of supreme beatitude. One of these, in the guise of a beautiful girl, meets and engages the affections of a young man. In the course of their acquaintance she warns him against the machinations of a sister spirit, who is a murderess and trying to entrap him, and insures his safety by giving him a charm. Presently an exorcist comes to the house in search of the little coterie to whom these stygian sprites belong, and succeeds in getting them tightly corked in his bottles. The lover, however, upon entreaty from his charmer, releases her and she escapes. Ten years afterwards she reappears, but, when urged to remain, says that her conduct during this term of probation having been pronounced satisfactory she is entitled to her celestial reward. Out of gratitude she tells her admirer when he is to die and join her in a state of perennial bliss.[1]

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[1] Giles's version of "Miss Quarta Hu," in Strange Stories, p. 152.

Stories of this type suggest the characteristic element of the Undine or Melusina group of legends in Keltic mythology. Here a nymph or fay desires an immortal soul or escape from enchantment,[1] which can only be secured by union with a mortal. In Europe the condition imposed upon the man is finally broken. Undine, for example, is brought to a stream in violation of the contract with her lover, and in a quite pardonable transport she subsequently kisses him to death. So it is in the Hindu tales belonging to the same family group, as in the experience of Urvaçi, an apsaras, or heavenly maiden, who obtained the mortal Puravaras as bridegroom upon the condition that she should never see him naked. The infraction in this case was not, like Psyche's, due to her own weakness, but to the jealousy of her celestial companions, who most unfairly enticed him from bed one dark night and then revealed his nudity to his wife by a flash of lightning.

The wanderings of a soul while the body is still alive are not imagined alone in the East. Dreamland travels are, of course, familiar experiences everywhere, and there is no great step from belief in sleep-absence to belief in a longer absence during trance. In Asia generally there is a settled conviction that the soul departs from its mortal frame while unconscious, and the greatest care is exercised by friends of a sleeper not to move his body lest the wandering soul fail to discover it upon her return, and death result. Meantime the soul in its excursions may be animating some other body, human or animal; hence the motive of many a strange tale like the following, which may bear quotation in extenso as a fair example of the Chinese märchen typically developed. It is entitled:

THE PARROT.

A young savant of the province of Shensi had six fingers on one of his hands; more than this, his character was one of singular naïveté.

Whenever he found himself in a social gathering where there were ladies, he was sure to run away. If a woman came up to speak with him, he blushed to the neck. Everyone made fun of his timidity and gave him the name of the "Innocent Sêng."

In the same district there dwelt a great merchant, who was richer than princes and nobly connected as well; he had a daughter named A-Pao, whose beauty was famous. She had already reached a marriageable age, but was extremely hard to please in the choice of a spouse.

The innocent Sêng had just lost his betrothed. To rally him, they told him that he ought to make his addresses to Miss A-Pao. This he actually did, thinking he was following good advice. But owing to his poverty his proposal was not favorably received. The go-between

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[1] Baring-Gould, "Curious Myths," Philadelphia, 1869, p. 488.

in leaving her father's house met A-Pao herself and asked her privately if for her part she would consent to this union.

"If he will cut off his sixth finger," said A-Pao, laughing, "I'll marry him."

This reply was brought back to Sêng, who, taking things seriously, as usual, seized a knife and rid himself by a single blow of the finger which he believed to be the sole obstacle that lay between him and a brilliant marriage. The pain was intense and the loss of blood so great that for several days he lay between life and death. When he recovered, he hastened to show his hand to the go-between and beg her to obtain for him that of A-Pao.

But the young girl, getting more and more exacting, now insisted that Sêng should rid himself of the mania of taking even the lightest things so seriously. The artless fellow understood at length that they had been amusing themselves at his expense, and, having no means of himself demanding an explanation from the young girl, he soon felt his first enthusiasm for her cooling. He consoled himself by declaring that A-Pao could not possibly be a serious person, and that he ought not to regret not having married her.

Upon the Fête of the Dead his friends proposed to him a stroll to the cemetery, hoping to meet someone who would suit his fancy. Perchance their good luck might bring them across A-Pao. And in fact they did see the beauty seated under a tree, surrounded by a crowd of youths who formed a wall of admirers round about her. Indeed, her beauty was unequaled and worthy of all this homage. While the others praised the young girl's beautiful face in speeches of labored eloquence Sêng remained silent. When the people had gone away and even the girl had left her seat, he remained alone, motionless, not answering a word to the appeals of his friends. They slapped him on the shoulder, saying: "Has your soul gone off with A-Pao?"

It was no use. He hadn't even sense enough left to understand what was said to him. So they took him home. He kept his bed as though he were drunk. From time to time he would reply to those about him a single phrase—that he was with A-Pao.

After that meeting it seemed to him that he had gone before the loved one, accompanying her to her home, and that since then he had not left her side. On her part the young girl saw every night in her dreams a young man who called himself Sêng. Shame alone kept her from telling her parents of these secret visions.

Meanwhile, the body of Sêng remained to all appearances entirely without animation as though fluttering on the edge of eternity. At length permission was asked of the father of A-Pao to send priests to his house to call back the soul that kept his daughter's company. "We have nothing to do with one another," said he, wondering; "how can his soul be detained here?"

Finally, yielding to the tears and entreaties of the sick man's family, he consented to having the Taoist ceremony performed. The young girl was greatly struck by this coincidence, and in the depths of her heart was touched by the profound love she had inspired. The youth revived, thanks to the exorcism, but was grieved no longer to see her by whose side he had been so entirely happy. He only awaited from that moment an opportunity to meet her again.

One day he learned that she was going to the temple. He arose in the early morning to go and watch in a spot where the carriage would pass. A-Pao came, toward midday, and at sight of the young man deigned to raise the curtain a little so as to see him; she even sent a maid to inquire his name. On reaching home Sêng fell ill as before, with this melancholy difference, that his soul could not as on the first time go forth and dwell with A-Pao.

One afternoon, seeing one of the children of the household playing by his pillow with a dead parrot, he thought if only his soul could enter the parrot's body he might in this way fly to his beloved's chamber. Hardly had this thought occurred to him than the parrot started up alive, took its flight and reached the room of the young girl, who eagerly caught it without its making the least resistance. When she was going to put a ring around its leg, it cried out: "Do not chain me; I am Sêng!"

"Your great love has made a deep impression on my heart," said the young girl, with joyous surprise. "But we are no longer of the same species; how can we ever fulfill our vows?"

"The happiness of being near you is enough for me," replied the parrot; "I ask no more."

He ate out of no hand but that of the girl. When she sat down, he perched on her knee; when she went to bed, he slept by her side. A-Pao loved him tenderly; too much, indeed, to want to have him remain a parrot. She sent her servant to inquire after the condition of her lover's body; they said that his breast was still warm.

"If you could become a man again," said A-Pao, caressing the parrot, "I will swear to give myself to you."

The parrot appeared to reflect a minute and suddenly took flight, carrying off in his beak one of the young girl's slippers. He flew straight away in spite of his mistress's call.

Sêng's family who were all in tears standing around the body were surprised to see it suddenly move and sit up at the very moment when a parrot came in by the window and fell dead on a mat in the chamber.

A-Pao seeing her dear bird disappear, sent an old serving woman quickly to witness the changing of the soul which she knew would take place, and to reclaim her slipper.

"The slipper is a promise," said Sêng; "I shall keep it until the day when that promise is made good."

A-Pao's mother, when she was made aware of these extraordinary events, was quite willing to consent to a marriage; but the father could not endure the idea of having a son-in-law at once poor and demented, and he persisted in refusing. His resistance was overcome by the threat which the young girl made of putting an end to her life. When the youth learned the good news, he became well all at once.

The following day the wedding was celebrated.

After three years of this happy union Sêng died. A-Pao would not survive him, and sought means to commit suicide so as to follow him into the other world. Fortunately those about her prevented her from carrying out this dreadful determination. At the moment when they were putting the dear husband's body into the tomb, what was A-Pao's joy to hear him groan and speak from beneath the grave-clothes! Sêng had come to life again.

Upon descending into the lower world he had seen the great god there who had already appointed him to some subordinate position, when the steward suddenly announced the immediate arrival of his wife; taking pity upon a love so complete, the god allowed Sêng to return to life.

"That is why you see me here," he added, pressing A-Pao to his heart.

It must not be thought that this insufficient résumé exhausts the category of strange resemblances between the folk-lore of the Far East and West. It is evident to the most superficial student that critical and scientific work in the field of Farther Asia has only yet been begun. Much remains to be accomplished in the merely preliminary labor of collection and classification; after this has been done in every locality there remains the greater task of assimilation and comparison with kindred conceptions found among other races. Hic labor, hic opus est; and no one can well comprehend the magnitude of the operation who has not, whether by choice or by chance, been brought into contact with the vast accumulations of material yet untouched. In this research there await at every turn fascinating opportunities for comparison with our own familiar nursery and tap-house acquaintances. What shall we say upon discovering in Korea the widow's cruse of Scripture lore—only that here the miracle is applied to a wine instead of an oil jug? Or to a Japanese version of the mediæval witch's spell laid upon her victim by means of a waxen image? Or to Ali Baba's open sesame in Tibet; or to Punchinello and all that he implies in the Middle Kingdom? These are but samples of the rich harvest to be gathered for the sociologist, the mythologist, the student of comparative institutions of the future. Though the contribution to science may fall short of expectation, much will be effected if we establish thereby the intellectual community of races, the brotherhood of mankind.

THE LOOT OF THE IMPERIAL SUMMER PALACE AT PEKIN.[1]

By COUNT D'HÉRISSON,
Secretary and interpreter to General Montauban.

[*Note.*—While China is occupying so much attention it seems opportune to republish a document of great ethnological value, both for its most interesting description of the great summer palace and the treasures it contained, its apparently fair account of the mental processes of the Chinese ruling classes and their attitude toward foreigners, and the frank statement of the uncontrollableness and barbarism into which trained European soldiers may relapse under temptation.

The Imperial Government of China was at this time (1860) under great embarrassment from what was known as the Tai-ping rebellion, and the rebels were ravaging the country in armies so powerful as to threaten the safety of the dynasty. Meanwhile an expedition of French and English troops was sent to Pekin to insist upon the ratification of the treaty made in 1858 with the English commissioners at Tientsin, with the understanding that it would be concluded at Pekin in 1859. Baron Gros and Lord Elgin were the diplomatic representatives of France and England, and General Montauban and Sir Hope Grant were the immediate heads of the French and English armies.

During 1859 an armed English force started for Pekin, but was repulsed at Taku in its attack upon the forts, and returned to Shanghai to wait for the arrival of a larger army.

On August 1, 1860, the allied armies landed at Pei-tang, a village 12 miles north of Taku. The forts were taken, and again the Chinese endeavored to persuade the allies not to move in force upon Pekin, but to send diplomatic representatives with a small escort. The French were inclined to agree to this proposal, but the English disapproved. Events proved the correctness of the position of the latter, since in the course of this march they encountered a Chinese army of nearly 60,000 men, arriving on the outskirts of the Imperial City on October 6. It was the intention of the generals of both armies for the moment to preserve the great palace, but while commissioners were deciding upon the disposition to be made of the treasures found in it, and as the result of a shot fired and a panic, the French troops and some English troops, the coolies, and camp followers rushed past the guards, and the unauthorized pillage described in the article, and lasting over the 7th and 8th of October, ensued.

The reader should note these dates in connection with the date of the quite subsequent destruction of the palace authorized by Lord Elgin on October 18.

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[1] Extracts translated from the "Journal d'un Interprète en Chine, par le Comte D'Hérisson. Nouvelle édition, Paris, 1901."

A few days after the pillage both armies were horrified by the appearance of 11 wretched men, all who had survived from a party of French and English who had been made prisoners, while acting as envoys under an invitation from the Chinese authorities, and tortured, accompanied by the bodies of those who had succumbed to the dreadful tortures inflicted upon them. The bodies were buried in the Russian cemetery near Pekin, with impressive ceremonies. On October 18 Lord Elgin ordered the destruction of the Summer Palace (Yuenmingyuen). He says:[1]

"I had reason to believe that it was an act which was calculated to produce a greater effect in China and on the Emperor than persons who look on from a distance may suppose. It was the Emperor's favorite residence, and its destruction could not fail to be a blow to his pride as well as to his feelings.. To this place he brought our hapless countrymen in order that they might undergo their severest tortures within its precincts. * * * As almost all the valuables had already been taken from the palace, the army would go there, not to pillage, but to mark by a solemn act of retribution the horror and indignation with which we were inspired by the perpetration of a great crime. The punishment was one which would fall, not on the people, who may be comparatively innocent, but exclusively on the Emperor, whose direct personal responsibility for the crime committed is established, not only by the treatment of the prisoners at Yuenmingyuen, but also by the edict in which he offered a pecuniary reward for the heads of the foreigners."

The above, it will be noticed, is the account given by the English of the reasons for the destruction of the palace. It will be noted that the enormous unauthorized pillage had already taken place, before the troops had learned of the alleged ill-treatment of the envoys, and that except the building itself there was little left for the English army to destroy when the official order was given.

It is to be regretted that we have not the Chinese story of the whole transaction, as the fairminded reader will wish to hear both sides.

The writer of the volume, from which the extracts following were made and translated, was, at the time of the events narrated, a very young officer, but extremely intelligent, and the author since of other valuable works. He was secretary and interpreter to General Montauban.

The disposition of the Chinese toward foreigners may be illustrated by some extracts which are made from the narrative, before coming to its most interesting portion, the loot of the Summer Palace.—S. P. LANGLEY.]

* * * Colonel Schmitz and Commandant Campenon entered a mandarin's house, surrounded by great gardens, and were struck dumb by this spectacle: In the principal chamber on the ground floor there was, as is usual in northern China, a sort of great bed, taking up all of one of the sides of the room. The bed, which is hollow, is made of bricks and is a kind of heating apparatus containing a furnace which opens on the outside of the house so that the "bed" keeps warm all the winter. On it are heaped mattresses covered with silk, and cushions and hangings, and there the family passes its time.

On this bed were extended three women—an old woman simply clad and two younger clothed in sumptuous dresses, one of whom was remarkably pretty. The throats of all three were cut, the wounds were gaping and the silk hangings were stained with the purple blood from them, which was flowing and falling in a cascade on the

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[1] Elgin's Letters and Journals, p. 366, quoted in The Middle Kingdom, Williams, p. 685.

floor. The women were still breathing, with their members shaking in the last spasm of the death agony. Beside them, two little girls were toying with the long, black tresses of the dying women, and playing hide and seek with each other in the blood-stained clothing, laughing at the singular movements of their young mothers or their great sisters. The faces of the children were smirched with the blood like those of babies eating jam. Opposite the bed, seated in an arm chair of teak wood against the wall and looking at this horrible spectacle, was the mandarin, the head of the family, who, to save these unhappy beings—probably his mother and his two wives from the outrages of the barbarians, had sacrificed them himself. His heart or his hand had failed him when he came to the two little beings who were still alive. He had opened his own throat with a razor, and, superb in his robes of silk, immovable, he sat there still alive. Through the open gash the blood flowed at every respiratory movement along his breast and fell upon the open razor lying on the floor. In his right hand he held his fan, which he used to drive away the greedy flies who were gathering on the frightful wound, and, under the fanning, the blood was already hardening and becoming brown. His eye, still hard and keen, was fixed firmly on the two terrified officers.

Schmitz and Campenon left, taking away the two little orphans, whom they put in charge of the chief almoner of the army, who sent them to Shanghai, where they were charitably cared for.

After hearing such things, the first thought that struck me was this: "If these people," said I to myself, "have such a horror of us that they do not hesitate to kill their own families and themselves, rather than suffer any contact with us, what treatment, great Heaven! would they have for those of us who were unfortunate enough to fall into their hands. What treatment?", alas, the future was to tell us!

Later, Lord Elgin came to see the General and gave him part of the papers which were found on one of the mandarins who had cut his own throat in the camp of Sinko. Among these papers was an edict of the Emperor of China, ordering his subjects to kill the invading Europeans like evil beasts. Here is the official edict:

"MANIFESTO OF THE EMPEROR OF CHINA AFTER THE CAPTURE OF THE FORTS OF PEI-HO.

"Scarcely had the barbarians endeavored to force the passage of Taku, when, in the twinkling of an eye, all their vessels were sunk, and thousands of corpses floated on the water for more than a league in distance. Some had succeeded in escaping and carried to their friends the news of this terrible punishment.

"I thought that this lesson would have sufficed to make them more circumspect. But who would believe it! Scarcely one year has elapsed since the memorable victory for our arms, and here they are back again, more numerous and more arrogant than ever.

"Profiting by the low tide, they disembarked at Peitang and attacked the formidable intrenchments of Taku; but, barbarians as they are, they attacked them by night and from behind. In this way they were able to surprise our troops, accustomed to see themselves faced by a courageous enemy, and unable to imagine that such perfidy and deceit could be employed against them. Now encouraged by this success, which should have covered them with shame, they have dared to march upon Tientsin; but my anger will reach them there, and for them there will be no mercy. Therefore we order all our subjects—soldiers and laborers, residents of the town and of the country, Chinese and Tartars—to destroy them like noxious animals. We order our mandarins and officers, both military and civil, to cause the people under their control to evacuate every city and hamlet towards which these miserable strangers appear to be going. They must equally destroy, by fire and water, all the food and the provisions which they would be forced to abandon. In this manner this wretched race, hunted by fire and by famine, will soon perish like fish in a tank that has been drained.

"Given at Yuenmingyuen the twenty-third day of the tenth month of the ninth year of our reign."

Another edict issued at this time put a price upon the heads of the barbarians. It made known to the people that for the heads of ambassadors 12,000 francs would be paid, for those of generals, 8,000, and so on.

[Immediately after this, Count D'Hérisson gives a spirited account of the attack of the allied armies on the Taku fort, which they captured, but with very considerable loss. His tribute to the courage of the Chinese should be given.]

The few men who had no time to fly before we took possession stood massed, upright, and motionless. They had thrown their arms down before them in a heap, and what arms, good Lord! Guns, discharged by slow fuses, of most incredibly ancient forms, generally quite harmless, and painted red; bows, crossbows, some lances, and bad sabers. We could not but ask ourselves how, with such means, they could have done us the harm that they did. It was not their armies which had been so fatal to us; it was their desperate bravery. They pushed back with their hands, as in the ancient sieges, the ladders which were covered with our charging marines; they threw onto our men their guns, their bullets, fragments of our own shells, and stones, and all those who had been ordered to defend the ramparts bravely died at their posts.

As in the camp at Sinko, we found in the mandarin's tent the corpses of some of these dignitaries who had stoically cut their throats. One of them, the highest in rank, no doubt must have been a very great personage, for his costume was not only rich, but decorated with the peacock feather, and we learned afterwards that he was the commandant of the forts of the left bank.

Immediately after the taking of the first fort, the Chinese hoisted a white flag on the second one and sent representatives to confer with our officers. The two parties met with courteous salutations, and after the customary "ching ching," the mandarins asked to be introduced to the ambassadors. The mandarin, who was the bearer of the flag of truce and who was of an inferior rank, was informed that the ambassadors were not there. "It is unfortunate," he replied, "we have got a letter to give them which authorizes them to enter into the Peiho, provided that hostilities are suspended."

The Chinese are our masters in diplomacy, and they have recently proved it. Now, at that time they were no more stupid than they are to-day. They had used, and they always have used, unlimited postponements, for a Chinaman will be eighteen years in discussing the place of a comma in a diplomatic paper. To him it is all the same; he is never in a hurry, and time is nothing to him, and it is this indifference to time which constitutes the strength of the court of Pekin.

The Chinese then began to go through their diplomatic procedures with our officers, but fortunately Mr. Parkes, one of the most skillful agents that England has ever had in the Celestial Empire, took charge of the conversation, and replied that the propositions contained in their letters were simply laughable, and that the officers for whom he was interpreting had only to demand the surrender of the forts. The mandarins replied that in this case they must retire; that the fort was well armed, and that the Europeans might come and take it. General Montauban was for an immediate attack, but his English colleague proposed to give the Chinese two hours. The allied officers sent to parley were received by a mandarin of elevated rank, a chief of high stature and martial bearing, who endeavored to gain time, but he was assured that if the forts were not surrendered in two hours they were to be attacked. "Well," said he, "try it. We have powder and cannon and we will know how to meet you."

At the end of the time our forces marched on the fort in a solemn silence. We marched on, leaving our first conquest behind, expecting that the Chinese would open fire at once, but no cannon shot came: nothing at all happened, and this silence excited the suspicions of our generals, who asked if the enemy was only letting us approach nearer to bring us within the range of grape. The army halted within gunshot; Captain Bovet, of the engineers, advanced and laid planks over the first ditch, followed by the general and the assaulting column; everybody followed him, and while we were asking ourselves what infernal stratagem was hidden under this silence, and were expecting to see the formidable artillery which we beheld before us begin to fire, we saw all at once the general and his soldiers on the rampart. Two minutes later we saw the great door of the fortress open; we entered and beheld something unexpected, for all the garrison, 3,000 men, were massed there motionless, the Chinese prisoners having thrown their arms in heaps before them.

The general approached, and by his order I asked some of them where their chief was. "We have none," they said. "Where, then, are your subaltern officers?" Three mandarins of no importance came forward and explained that the chief general had been killed in the other fort: he was the man who had the peacock plume, and nobody, they said, had dared to take the command afterwards without the Emperor's orders. The ability of a chief comes to him from the Emperor through the orders which he transmits, and whoever is vain enough to assume himself the responsibilities of such command can only commit faults; and, they added, "if the mandarin invested with supreme power could not defend the first fort, how could we have any pretension of doing better than our commanding officer did?" After this discourse, so full of good sense and respect for official order, the three lower class mandarins knelt down, beat their breasts and asked to be sent to the right bank. * * * It was evident that the demoralization of the Chinese, to which we owed the surrender of perfectly defendable fortresses, came from the death of the commanding general, who was said to be the own brother of San-Ko-Li-Tsin, the commander in chief of the Chinese army.

[Count D'Hérisson, after giving the history of the subsequent negotiations, in which it was arranged that the ambassadors should go to the capital to finally ratify a new treaty there, refers to the delicate question which arose as to the number of persons in the escort which the ambassadors should take with them to Pekin. The Chinese insisted that this escort should be a very small one, reasoning as follows:]

"You are treating with us to secure your interests and protection for your commerce, and it is in your own interests then not to diminish the prestige of our sovereign. You have everything to gain on the other hand while leaving him the moral force necessary to execute the treaty and to guarantee the favors he has conceded. If you arrive at Pekin with your victorious generals escorted by their armies, our Emperor will appear in the eyes of his subjects to yield to force, and you will have no occasion for surprise if in spite of his good will you do not find him giving with a good grace."

Baron Gros, the French ambassador, would have been satisfied with an escort of a few men, but Lord Elgin did not view it at all in the same way and would not go to Pekin except surrounded by a force sufficient to represent properly a great nation and a great Queen. He demanded an escort of at least 1,000 men—infantry, cavalry, and artillery. The French General (Montauban) himself did not share this opinion, and supported the French ambassador. He could not imagine the possibility of treason on the part of the Chinese, and the general wrote to the French minister of war, complaining that our allies were compromising the result of so successful a campaign out of their puerile vanity in exhibiting their forces. He wished to explain that he was not responsible for the fatal consequences which such a show of force might bring about, * * * but the English were right a hundred times over. If we had listened to Baron Gros, if the Chinese had only waited a fortnight longer before showing their hand, not one of those who would have left for Pekin would have ever come away alive, and the defeated army, deprived of its leaders, would have been massacred at the gates of Tientsin with no one to return to Europe to bring the news of this tremendous disaster.

On the 10th of September we left Tientsin (for Pekin) with 3,000 men and two batteries of artillery, the English being in equal force. The twelfth day, when we were at Yangtsoun, an incident occurred. A mandarin of low rank, but lofty stature, asked to speak to the French general, and I was directed to interpret. He was hardly seated when he asked the general to consent to having the troops follow some other than the main road, which went through two villages belonging to him, asking that the villages should be left on one side, and proposing in exchange that he would bring provisions to the army. The general replied that the route had been laid down in advance and that the army would follow it without paying any attention to the villages, whose inhabitants need have no occasion for alarm.

The Chinaman laid his hand on my arm and said, "Just understand this. There are 1,000 taels for *you* if you will decide your chief not to have his troops go through these villages." "What is he saying?" asked the general, who, while we were talking, was playing with a great pair of spectacles which the mandarin had laid down on the table. He had been trying them on, and gave a joyful cry to find that they were fitted to his sight. (I ought to say that two days before the general had lost his own spectacles.) "He says, General, that there are 7,000 francs for me if I can induce you to proceed by a different route than that toward these villages." "Ah, he says that, does he?" remarked the general. "Well, tell him that he is a rascal, but that I pardon him this time; but as every bad action deserves a punishment, I shall keep his spectacles." While complying, I pushed the tall mandarin toward the door, and I can not describe the astonishment with which he saluted the general, whom he saw wearing his own spectacles. As he went over the threshold, he said to me, "If 1,000 taels were not enough, why didn't you say so?" this being the only moral that he drew from the interview.

When General Montauban returned to France there were persons jealous enough to state that he had only gone to China to pillage, and these insinuations were made after the affair of the summer palace that I am going later to describe.

I, who had not quitted the general a moment from his departure from France until the last day of the expedition, would like to give my word of honor that the only thing which he ever looted in China was this pair of spectacles, worth not more than thirty-nine cents.

We arrived on the 13th at Hosiou and saw before us everywhere the still fresh traces of the camps of large bodies of cavalry, and now I understood the object of the mandarin, who wanted us to change our route so that we should not see this for ourselves.

The general was completely cured of the confidence which had made him object to the insistence of the demands of the English on arriving at Pekin in force. He felt instinctively that something wrong was going on around him, and he wanted to have all his people in hand.

Before the allies quitted Hosiou and occupied Tangtcheou, Prince Tsai had sent two men with new dispatches which were addressed to Baron Gros, stating, among other things, "If you consent to encamp your army without advancing in the villages of Yangtsoun, Tchountchou, and Hosiou, your excellency, according to our agreement at Tientsin, can go with a very small suite and without any arms to Tangtcheou and there we will come to an understanding on all the articles of the convention, which we have agreed to and which we can sign and seal before your excellency goes to the capital. In this way all delay will be avoided, and the Chinese troops will be directed to procure your excellency wagons and everything necessary for the journey, and we beg that you will give us a statement of the number of persons who will accompany you, so that we can prepare everything in advance."

(Signed, "The Imperial Ambassadors, Prince Tsai Y'tsin, etc., the 13th of September, 1860.")

Baron Gros once more believed that everything was arranged for the best, and again was the dupe of the Chinese, having learned nothing by his previous experience of their tortuous diplomacy. He stopped the army, then two leagues from Tangtcheou. Negotiations were going on, and there seemed, therefore, no danger in sending officers with a flag of truce to Tangtcheou, and the general sent Sub-intendant Dubut, Colonel Foulon, Captain Chanoine, and administrative officers Ader and Gagey, while the Abbe Duluc, a missionary, went with them as interpreter. They were also to collect provisions and arrange for the material comfort of the troops conformably with the instructions of the ambassadors.

In accordance with our understanding with them the following English officers went along: Colonel Walker, Lieutenant Anderson, Mr. Bowlby, correspondent of the Times, and M. de Normann, first secretary of the embassy, with Messrs. Loch and Parkes, nineteen Indian horsemen forming their escort. M. d'Escayrac de Lauture, Count Bastard, Çaid Osman, and M. de Meritens accompanied and formed a part of this little expedition to carry to Prince Tsai, Baron Gros's dispatches. They left Hosiou and the army was to follow in their traces, they having gone on before to arrange for the camping places on the road to the city.

On the 18th the army struck camp, with the English at the head of the column. They marched forward for two hours, when a captain notified the general that there was a large Tartar army in the way. Very uneasy, but more and more satisfied that he had brought a strong force with him, General Montauban went to confer with his colleague, where he found a high mandarin accompanied by a numerous retinue. This functionary, who was called Hang-Ki and who had a rank equal to that of one of our generals, stated that he came to arrange with the ambassadors the ceremonial of their entry into Pekin. The general replied that the ambassadors had not come with the advance guard, and that he would like to know why the place where they had expected to stop was occupied by a Tartar army.

A Chinaman is never taken by surprise. Hang Ki, pretending to be astonished, asked our general about these troops of whom they spoke, which he said they had never heard of, and took his leave, saying that there must be some misunderstanding.

At this moment Captain Chanoine came in and informed the general that he had in front of him a Tartar army of 30,000 men (15,000 horses, and as many foot), and presently clouds of dust were seen on the horizon, due to marching troops.

The generals found themselves in a critical situation, for they had but few troops in comparison to such a mass of the enemy as was drawn up in battle array. General Montauban considered it debatable whether they should take the offensive, but decided that we must fall upon the enemy, as there was no other way to save our unhappy officers who had just been dispatched to Tangtcheou. General Grant, on the contrary, thought that there was no evidence that our officers had been made prisoners, since two of them had come back.

At this stage arrived M. Bastard, M. de Meritens, and Çaid Osman, and confirmed in every respect the statements made by Captains Chanoine and Gagey. There was no room for doubt that in obeying the proclamation of the Son of Heaven, who had enjoined them to exterminate the Europeans by every possible means, the Chinese were developing a traitorous plan begun at Tientsin and had drawn us into an actual ambush, hoping to destroy us by their number.

Presently we heard the gallop of a horse in disorder and saw Colonel Walker arrive, followed by two wounded horsemen; he himself was wounded in the arm and one of the horses fell dead at the feet of the general. He related that he had left Tangtcheou at an early hour and rode into the enemy's camp, affecting to be perfectly calm, but observing carefully what was passing about him. The Chinese officers urged him to dismount and go into their tent; he had happily refused and certainly owed his life to the refusal. M. Ader had been attacked by several Chinese, and, with his orderly, defended themselves with desperate courage; it was impossible to give any help to them, for he was separated from them by an entire regiment, and had enough to do to save himself. The Chinese no longer asked him to visit their tent, but attacked him and his escort. He and his men took their bridles in their teeth, their sabers in their hands, and, urging their horses, succeeded in overturning those about them and forcing their way through, and in spite of the fusillade, though the riders and horses were injured by the balls, no one was dismounted. Upon seeing their escape, the Chinese fired three cannon shots, the signal for the battle.

[The author describes the fight, under these circumstances, of the French and English armies, who had to conquer or die on the spot. They conquered, putting the Chinese to rout.]

Hardly was the combat over when a common thought occupied us all—what had become of our European officers shut up in Tangtcheou? Those who had escaped and whose return I have mentioned had told us what they saw on the 17th in the afternoon when they arrived in the city. The mandarins had received them most courteously, undertaking to conduct them to lodgings prepared for them in advance. De Lauture, his secretary, and two soldiers followed one of these mandarins and were taken to the Yamen. The others had gone to interview the Chinese functionaries who were to aid them in the supply of food for our troops.

M. Bastard had asked an audience of Prince Tsai. The conversation was cordial, but the prince was now preparing to trick our poor secretary of embassy, playing with him as a cat plays with a mouse. He approved all the terms of our ambassador's dispatch, and only objected to the demand for escort of 1,000 men, which, however, he conceded with a faint smile. Baron Gros (our ambassador) had asked his secretary to demand letters of credence for this Chinese plenipotentiary. In the face of this matter-of-course demand, the Chinese functionary could not conceal a movement of anger, and replied that he would agree to the request, but that he must express his lively indignation at such a demand being made of him; of him, who, he said, had never lied, whose authority was superior to that of all plenipotentiaries, and whose signature was as valid as that of the Emperor's.

It must be remembered that while he was talking in this way to the French representative the Chinese were massing their troops and were charging their cannon. Do not forget, either, that the Chinese of today have the same character that they had then.

After having received the official reply of the prince, M. Bastard started early in the morning to regain the French camp, escaping miraculously from the hands of these wretches, though at the ultimate cost of his life, his experiences having developed the germ of some cerebral malady from which he died.

As to those of our people who had not been able to get back, about thirty in all, we did not know what had become of them. We only knew the fate of the unfortunate Ader and his heroic orderly, whom Colonel Walker had seen killed; but Chinese spies told us that they had seen a certain number of European prisoners taken in the direction of Pekin. The reader will see what fearful tortures were inflicted on these unhappy beings, and in what condition they were brought back to us, alive or dead.

The Chinese reports were true and the Chinese army was taking them to Pekin after Palikao, of which I shall presently relate. Two of them were beheaded on the field of battle—an English officer and the Abbé Duluc. Afterwards when the bishop of Pekin came to Palikao to look for the remains of the victims nothing was found, and it was supposed that the dogs which had been feeding on the corpses had devoured them.

After the battle of Changkiawan, which is the name of that just described, officers were sent under a strong escort to declare to the taotai of Tangtcheou that if our compatriots were not returned to us we would march on to Pekin, and those who had so traitorously surprised them would be held responsible. The taotai replied that they were gone, and he knew nothing about it. There was nothing to do then but go on to the immense Chinese capital to terrify its sovereign and to obtain the surrender of the prisoners at any cost; the army was unanimous on this point, from the general to the drummer boy; everybody said, we must have them back if we die here!

We were about to march forward, but this time into the unknown, without any diplomatic errand, since the negotiations were broken and the negotiators dispersed; we were going, if I may use the expression, to hit back until the Chinese begged for mercy. The small allied force the next day found itself in the presence of a still larger army, and again fought for its life.

One incident of the battle may be mentioned. The Chinese were drawn up beyond the bridge of Palikao (a very fine one in stone and and marble). Their army numbered about 50,000 men; there was at the entrance of the bridge a Tartar of gigantic size, a sort of flag bearer of the generalissimo, holding an immense yellow banner with black characters, which he inclined in every direction, and on which the eyes of the generals were fixed, for it transmitted the orders to the whole Chinese army.

The enemy was in full retreat; the field of battle and the bridge, which the flower of the army had defended, were filled with corpses, but this Tartar still stood there alone, abandoned by his comrades, and bravely transmitting the orders which he had received. The shells burst and the bullets whistled around him, but he remained immovable; his courage was sublime, and General Montauban exclaimed, "What a brave man! Save him!" Some soldiers sprang forward to try to take him prisoner, but at this moment the hail of grape which had spared him, as if to give us time to fix his heroic form in our memories, cut him down, and the great banner flew away, carrying with it attached to its pole the arm which had sustained it.

Our losses were insignificant, amounting to but 51 men for English and French, but the Chinese had left on the field a number of dead, which we estimated at 1,000; but which, according to the reports of their general, found at the summer palace, were 3,000. In the summer palace also were numberless small flags and the grand imperial flag. Along with the papers found in the summer palace was a letter saying we had been engaged with 60,000 men, and also another letter from San-Ko-Li-Tsin, dated at Hosiou, stating that he had informed the Emperor he was sure of exterminating the foreigners. This letter was dated the very day that Prince Tsai was saying he never lied, and giving his word of honor that peace would be made.

Certain that he could neither crush us nor resist us, the Son of Heaven had nothing left to do but to abandon his throne, or to treat with us, and he resigned himself to the latter decision, and this time it was his own brother, Prince Kong, who was charged with the negotiations.

It is the Chinese system to proportion the importance of the envoys to the importance of the difficulties which they are charged to meet. Since our arrival in China we had been meeting dignitaries of a higher and higher grade, and one really ought to see with what stolid faces these diplomats disallowed one another.

Prince Tsai had declared that he was not a liar, like his predecessor Koue Lian, and that his signature was as valid as that of the Emperor. Prince Kong declared that Tsai, having conducted affairs ill, had been disgraced, and that he, the brother of the Emperor, was going to put them in the right way. Our great preoccupation was the fate of our officers. The ambassadors replied that an unheard-of thing, which had never before been registered in the annals of mankind, had occurred at Tangtcheou; that the ambassador's envoys had been surprised and captured, and, we had reason to fear, bound and conducted to Pekin in carts, and that consequently negotiations would not be resumed until the prisoners had been sent back to our respective camps.

This was very plain, and there was need for but one word in reply; but "Yes" is not Chinese, (any more than "No," for that matter). He commenced an interminable statement to the effect that the prisoners were well, and would be returned as soon as the treaty of peace was signed; that their presence in Pekin was a guarantee of pacific intentions, etc., and days were spent in discussion.

It was necessary that we should finish with this Prince Kong, who would not give us our prisoners; but how? Neither Baron Gros nor the general had been sent to conquer the Chinese nor to overthrow the dynasty, whose representative was in flight; to change the dynasty would have been impossible, and it was necessary, then, to treat with Kong, and to treat effectively we had to appear ready to fight again.

On leaving Palikoa we encountered abominable roads, but traveled on in good spirits until the tall roofs of Pekin could be seen on the horizon. Pekin—that mysterious and gigantic city, which had seemed in our European dreams at such an immense distance—Pekin—at last, Pekin! Officers, one after another, climbed the brick furnaces, and up behind them scrambled the soldiers, stretching their eyes to catch a glimpse of the walls said to surround so many marvels and which none of them had ever expected to see.

The next day the march was resumed at dawn, and the ground became more and more difficult. Finally a long halt was made by the army at a distance of little over a mile from the northeast corner of Pekin. A few minutes later an orderly arrived from General Grant to inform the French commander that according to spies the Tartar army had retired to Yuenmingyuen, the magnificient imperial residence, for the probable purpose of protecting the Emperor, who was thought to be still in this, his autumn palace. Yuenmingyuen is in fact the autumn palace, which all Europeans call—I can not imagine why—the summer palace. General Grant announced that he was going to visit it, and begged his comrade to accompany him. Montauban, interrupting the conversation held with Lord Elgin, gave the necessary orders, and the march was resumed past Haitien, an unimportant town, where the palace in question is situated, which I, like the rest of the world, shall call, if you please, the summer palace.

The guide who accompanied Grant's orderly told us that the palace was about two miles off, but these two miles being very much like the "short half hour" of our French peasants; we marched for two hours, and did not reach the place. At last, after having made a dozen times the "two miles" announced by our guide, the French army arrived at Haitien just as the day began to wane.

Just as Versailles is an appendage of the palace of the great king, so Haitien is an annex to the palace of Yuenmingyuen. A broad street, flagged with granite, leads directly to the palace, crossing, 600 feet before reaching it, a monumental bridge thrown over the canal. It is then transformed into an avenue of venerable trees, bordered by houses inhabited by the mandarins of the court when the Son of Heaven deigns to show himself on earth in his summer palace.

The first companies to arrive halted in front of the palace, and soon the whole army was massed on the grand open square, which served as the court of honor, and which had very nearly the dimensions of the Place d'Armes at Versailles, but with the additional advantage of possessing splendid shade trees.

Before us rose the hermetically closed walls surrounding the palace, and stretching on either side beyond our vision. Quartermasters were marking the position of the tents of each company, and the order was about to be given to separate and stand at ease, when all of a sudden a gate opened, and a band of soldiers and servants discharged a volley of musketry upon the army.

Nothing is so impressionable as a body of troops gathered in a tumultuous group, particularly when they find themselves facing something unexpected. In the dusk, our men saw for the first time a regal building of magnificent aspect, and heard the magic word which had already secured an astounding prestige among them: "The Emperor!" so that the sudden panic which broke out on hearing these inoffensive shots was not surprising, even if it occurred in the midst of troops which had been victorious at every point since arriving in China, never recoiling a foot, and who did not consider that the fact of their plunging in such small number into the midst of a nation of 400,000,000 souls was an act of unheard-of heroism.

For a moment all was in disorder, confusion, and tumult; the disbanded soldiers ran in every direction, crying out. The general knew that an army is a string of pearls, easy to handle so long as the thread of discipline holds together the single elements, but helpless without military order, for the thread being broken the pearls fall to the ground, and he for a moment feared a disaster. He used his utmost endeavors, giving orders, swearing, persuading, reassuring, and finally thrust out his cane into the vacant air, as if to stop the disorganized and affrighted individuals. He lost his cane, which was snatched from his hands—by whom, no one ever knew.

The panic, fortunately, ceased of its own accord, no one having been injured by this first discharge. Only a single bullet hit anything, and this lodged in the head of a horse that belonged to Commander de Bouillé.

While order was being established and the army arranged its tents, the general sent one of his aids, Naval Lieutenant de Pina, at the head of a company of marines, to search the entrance of the palace, where several hundreds of the Tartar force which had caused us so much disturbance during the night might possibly be concealed.

He had been gone but a few minutes when firing was again heard, and the general sent a positive order by Lucy not to fire, fearing that the palace might be set on fire, or that his men might kill each other, and wishing that all should be taken by a bayonet charge. Lucy started, the musketry fire ceased, and this is what took place. On arriving at the great gate after the first discharge, M. de Pina had called the watchmen of the palace to open it; as there was no response, he had a ladder brought and climbed the wall, followed by M. Vivenot, a midshipman. Having reached the top of the wall, M. de Pina observed several Tartar soldiers in the courtyard, but he bravely jumped down, hoping to have time to open to his men the large gate, from the inside, before he could be attacked.

The Tartars rushed at him, he fired his revolver once or twice, and when in the act of taking aim at a third soldier he received a violent blow from a saber, which inflected a deep flesh wound, while almost at the same moment he was wounded in his left hand. M. Vivenot, who had jumped after him, received a bullet in his side, and the Tartars would have finished these two brave officers had not their men, who had scaled the wall in the meantime, come to their succor, and forced the Chinese to retreat. The latter withdrew, carrying off their wounded, and leaving three dead in the courtyard.

The great gate was opened, the first court was occupied by the Collineau brigade, and for greater security the gates which opened into the interior of the palace were barricaded without and guarded.

The capture of the palace had cost us the wounds of M. de Pina and M. Vivenot, as well as those of two marines, one sheep, and the general's walking stick.

The next morning the gates were unfastened and opened. All within was silent and deserted. General de Montauban penetrated into the palace accompanied by Generals Jamin and Collineau and Colonel Schmitz. I had the honor to follow these four officers.

The generals, from a feeling of delicacy, easy to comprehend, had wished that the first visit might be made in the presence of a delegation of English officers, whose troops were marching with us. None of these officers knew what had become of their general in chief, and the army, and cannon were fired every five minutes for an hour on the great square, to indicate to our allies the place where we could be found.

We five Frenchmen were joined by Brigadier Pattle, Major Sley, of the Queen's dragoons, and Colonel Fowley, and were preceded by a company of marines.

THE SUMMER PALACE.

To depict all the splendors before our astonished eyes, I should need to dissolve specimens of all known precious stones in liquid gold for ink, and to dip into it a diamond pen tipped with the fantasies of an oriental poet.

What struck me at first was this: Although built in a pure and elegant Chinese style, the summer palace furnished in its arrangement, its architecture, and even in certain of its details, singular reminiscences of the palace at Versailles, modified by the peculiarities of all Chinese constructions, which are never more than one story in height, having only a ground floor, without attics or mansard windows, with nothing to separate the roof from the rooms on the ground floor. This distant resemblance is not inexplicable.

The Jesuits, who played so important a part in China, who gave to it veritable Richelieus and Mazarins; the Jesuits, who remained in high honor as semi-sovereigns at Pekin until 1773, when their order was suppressed by Clement XIV; the Jesuits, as clever in administration as they are great in mathematics, who had in their order men having all talents and knowing all sciences, were in some sort the architects of the summer palace and the designers of the beautiful gardens.

At that epoch Louis XIV had sunk so many millions in Versailles that when he received detailed bills he ordered them to be paid and burned, hoping to conceal from posterity as well as from himself his royal folly. The echo of these splendors created by the Grand Monarch reverberated from country to country, transmitted by word of mouth throughout the world, and finally reached the ears of the Emperor of China.

The Son of Heaven found it strange and inappropriate that there should be on the earth a king who took the sacred emblem of the sun and who allowed himself treasures which he, the true Son of Heaven, had not secured. And what sort of a king? A mere kinglet, a man who governed a paltry handful of human beings, 25,000,000 souls, who was consequently only one-thirteenth of his own importance. And in this way, strange as the thing appears, Versailles gave birth, in some measure, on another continent, to the richness and magnificence of Yuenmingyuen. The palace was a long time in construction, and the Jesuits were succeeded by other missionaries, as artistic as themselves, who had but to embellish the original plans. But this is history enough; let us proceed.

At the end of the first court arose on three granite steps an immense hall, its naked walls unornamented save by a few inscriptions and having no furniture but high-backed wooden benches. It was here that his subjects awaited the honor of approaching His Majesty. Behind the hall on the same level stretches a second court, which separates it from the audience chamber; this court is furnished with vases of old porcelain four or five feet high, which serve to hold a quantity of little trees, each queerer than the other. * * * Take, for example, an oak. It is 200 years old; it does not resemble a young tree; on the contrary, it is an exact photographic reduction of a huge and venerable oak of the forest, but it is only three feet high. It is a perfect dwarf, and by the side of it is a group of six trees of different species, growing a few inches apart, in a single vase, which are united at the height of three feet into a single trunk, which branches out a little higher, producing leaves impossible to classify—and observe—the Chinese are not acquainted with grafting. These tricks are reproduced in all the large pots in varying forms. Generations of learned men have devoted their lives to the study of processes for cultivating these vegetable monstrosities, and presently, continuing our visit, we shall find on the shelves of ancient libraries the results of their studies, in well-labeled volumes.

We only gave a passing attention to the extravagant contents of these porcelain vases, of which the smallest would be worth 100,000 francs in Druot's auction rooms, and we went straight into the first audience room, which opened before us.

This hall forms one side of a quadrangle of buildings, in the midst of which is a garden and fountains; to the right and to the left are two other halls of audience and of ceremonies, and at the far end of the quadrangle the throne room.

In the three halls first traversed we found most extraordinary treasures. We must bear in mind that the Emperor preserved in these palaces—transformed into a museum, or rather into a warehouse of riches—the most exquisite products of many generations of 400,000,000 human beings, of which he is the demigod, as well as all the tributes paid him by foreign nations, all the presents which fear or admiration had drawn from the great as well as the humble, all which had been confiscated from his rebellious subjects. We must bear in mind that in this immense Empire not a superior work of art was produced which did not naturally drift toward the Emperor, and not a treasure was discovered that did not fall into his hands of its own accord.

There were gathered all the wealth in precious stones and fine fabrics presented by tributary princes, and all that the kings and emperors of Europe had sent to Hien-Fong and his predecessors, all the bric-a-brac and curiosities, as well as all the goods which the simple-minded merchant, wishing to obtain rights in a port, subtracted from his cargo to propitiate the sovereign. Everything was preserved with care and equally honored, from a cloth of gold ornamented with pearls, which had come, perhaps, from the Sublime Porte, up to a doll that cried "papa" and "mamma," which a Marseilles captain had taken from his little daughter at Christmas and carried to China to "grease the palm" of the chief mandarin.

This multitude of treasures had overflowed the private apartments of the sovereign and his wives and spread itself into these immense cathedral halls. The spectacle was at once extraordinary and dazzling—dazzling from the richness of the articles, extraordinary from their number and variety.

At length we reached the throne room, placed on a platform approached by seven steps of beautiful granite polished like a mirror. It is completely separated from surrounding buildings. Its raised roof, extending at least three feet beyond the granite steps, is supported by two rows of ironwood columns, most artistically engraved, and resembles those bamboos or engraved ivories which we in Europe use for tobacco jars or match boxes, but swollen to gigantic proportions. No two pillars were alike, and the scenes which were engraved in spirals around their shafts, as on the column in the Place Vendôme, were borrowed in part from national history, in part from legends, in part from celebrated romances and mythology.

The one against which I leaned, the only one of which I have a distinct recollection, pictured the life of the god of wine, whose skull is as high as the rest of his body. He is traveling, peacefully seated upon a buffalo, with a curved stick in his hand, and before reaching the top of the pillar he must pass precipices, enchanting landscapes and caverns where monsters lie in wait, and finally go under a triumphal arch surrounded by pretty women. It is a lively sort of a journey for the good deity and a symbol of the imaginary voyages which his followers make after too copious libations in his honor.

On the shafts of these columns all the surface of the wood not removed by chisels is covered with lacquer of dazzling colors; on the capitals the imperial dragon twists and rolls himself into all possible shapes, holding in his claws escutcheons covered with mottoes.

From these columns, where our gaze has been agreeably arrested, it ascends to the roof, and there it meets a magnificent spectacle. The roof is covered with those shining yellow tiles made in the little village where we spent last night, the ridges and the eaves being of green tiles as brilliant as the yellow ones, producing an elegant and majestic combination of colors. At the four lower angles of the roof immense dragons of green faïence are crouching, inestimable products of the city of Hangtchoufou; the enormous beasts appear to be climbing up the ridges of the roof; they gaze at each other in pairs, their jaws open and their eyes staring.

Finally, at the two ends of the coping a marine monster in green and black faïence springs at another monster facing him, and gayly raises heavenward a three-meter long tail, ending in a pinion which serves as a colossal double crest to the whole building, and gives to it a swaggering air, if one can apply such a word to a house.

In the sunlight, whose golden arrows are reflected in blinding array from these brilliant and gaudy surfaces, throwing its sparks into the eyeballs of the monsters, and its shadows into the abysses of their gaping jaws, the superb and magnificent building arises like an enormously magnified jewel.

Everything is clean and clear and intact in this masterpiece, over which the blue sky seems at the coming of night to close like a jewel case with a blue velvet lining. And the care of its preservation and maintenance is carried so far that wherever a wandering bird might place its tiny feet, it would find an invisible iron wire which would remove his desire to rest there.

The throne room is entered by a great opening without a door. The interior might be seen from without were the view not intercepted by a screen of teak wood, as big as the rood-screen of a cathedral—carved, inlaid, cut out like lace, and representing gods, and bounding men and horses—a room 160 yards long, 22 yards wide, and 17 yards high, such are its temple-like dimensions.

The throne faces the screen and is raised upon ten steps; it is a mountain of cushions and silk mattresses, in a niche nearly 25 feet wide, itself cut out of an immense lattice-work wainscoting, like an openwork alcove in the wood of the choir of one of our old cathedrals.

The hall is well lighted throughout, for the windows are close together, and furnished with ventilators, shades, and blinds, permitting the passage of refreshing air no matter what the position of the sun. On piers between the windows, frames of sculptured woodwork surround pictured panels.

There is scarcely any furniture; behind the screen is a little altar facing the throne, on the right of the imperial seat a table and an armchair of teak wood. On the table are a golden tray, some writing brushes, a saucer of vermilion, and some paper on which is traced characters in vermilion—it is the interrupted correspondence of His Majesty. On the small altar rest two incense burners of jade, some porcelain saucers, on which, in the absence of the Emperor, are placed fruits, tea, and flowers, offerings addressed to his spirit that in Chinese belief is always present in these places.

On either side of the throne, in the corners of the hall, are two doors, each leading to a kind of small saloon or oratory; that on the right communicating with the private apartments of the sovereign; it is called the *Tien*—heaven.

The walls, the ceilings, the dressing tables, the chairs, the footstools are all in gold, studded with gems. Rows of small gods in massy gold are carved with such wonderful skill that their artistic value is far beyond their intrinsic worth.

There, on supports of jade, are two pagodas of enameled gold, as large as corn bins, with seven superposed roofs, and from each pear-shaped pearls hang like so many bells. In among the gods are European clocks of every description. Two of them are of the beautiful Louis XVI style and are models of good taste, beauty, and fine workmanship; alongside are more incense burners, torches, candlesticks, golden boxes, snuffboxes embellished with precious stones, and enameled miniatures, a jeweler's fevered dream.

In the other oratory to the left, which resembles the interior of a monstrance, are gathered all the articles for the daily use of the "Son of Heaven," when occupying the throne room; his tea service, his cups; his pipes—the bowl of gold or silver—the long tubes enriched with coral, jade, rubies, sapphires, and little tufts of many colored silk; his ceremonial chaplets of rows of pearls as large as nuts, which are spread across his august breast, though their whiteness is not quite perfect. Here are his speaking trumpets of silver gilt, used at times to swell his voice to thunder tones for the benefit of his prostrate subjects. On wall cabinets are a great many little silver blades, with rounded ends, nearly half an inch thick, two inches wide and eight long, looking a good deal like our thermometers; these bear engraved characters, the chiseled lines being filled with gold. Etiquette requires you not to speak to the sovereign, not to even lift your eyes to his sacred person. If, however, he should ask "What time is it?" how can you reply without speaking or looking at him? With bowed head one of the silver tablets on which is inscribed the particular passing minute is presented to him; he glances at it and learns what he needs to know. It is very ingenious, but for my part I should prefer a good watch.

I shall not attempt to portray the wonder and admiration of the "barbarians" who penetrated into these precincts. Involuntarily we spoke in low tones, and began to walk on tiptoe on seeing before us such a profusion of riches for the possession of which mortals fight and die, and which their owner had abandoned in his flight as indifferently as a citizen closes the door of his house, leaving his mahogany bureau exposed to the chances of war. All was so natural, so familiar, so commonplace to him that he did not even try to save these treasures.

Behind the throne room, stretched over an immense space, in the midst of gardens, are the private apartments, likewise crowded with objects of luxury and beauty, but on the whole less extraordinary, for between the sleeping room of an emperor and that of a private person there is less difference than between a throne room and a parlor.

In the rooms of the Empress, the walls of the closets of the secretaries are furnished from top to bottom with pigeonholes, in which, one above another, like files of lawyers' briefs, are red boxes of old lacquer of Pekin, wonderfully engraved in intaglio, containing ornaments, necklaces, and bracelets in pearls, in jade, in precious stones, tiny rings for feminine fingers, and huge ones of jade, worn by men when they draw the strings of their bows.

Boxes not holding ornaments already mounted, are crowded with artistic objects, with materials to be transformed into jewels, with unique specimens of transparent jade, of rock crystal, of milky jade, of moss agates, of uncut diamonds, of precious stones still in their natural state; tea services, cups, saucers, a regular bazaar—not one where everything is quoted at 19 cents—but rather a bazaar where everything is worth 19,000 francs. On opening one of these boxes, it appeared to send out sparks and sheaves of light.

Beyond, great wardrobes of old lacquer set into the walls of the room contain the garments of the Empress, both those for daily use and for ceremonious occasions. There was enough to dress, from head to foot, 10,000 princesses from the "Arabian Nights," so that it would be impossible for the Caliph of Bagdad, a judge in such matters, to find occasion for changing the position of a single pin or to alter their arrangement. All is of silk, satin, damask, fur, with embroideries sometimes as delicate as spiders' webs, sometimes as heavy as those on bishops' copes; it is a brilliant display of birds, butterflies, and flowers fresher than those in the sun, with diamond dewdrops in their perfumed calixes.

Here and there footstools of strange shape allow the ladies-in-waiting to reach the high shelves where the toilets are, and offer nest-like cushions to their little crippled feet.

His Imperial Majesty, as everyone knows, does not content himself with a single wife. He has concubines, whose quarters are opposite his private apartments. These ladies, into whose rooms we throw a passing glance, our powers of attention being already wearied, are apparently almost as well cared for as their sovereign, and drink their tea from cups almost as precious as his own. When the Son of Heaven takes a cup of tea here he must perceive no difference.

At last we have finished with this endless fairy story and find ourselves face to face with nature, with fountains, and with foliage. What a magnificent park! It is immense, with high walls extending about eight and a half miles around it. Those who designed it took special pains to arrange picturesque views, giving impressions which were sometimes gentle and tender, sometimes savage and theatrical; and they succeeded.

But they assisted nature by architectural effects also, and this park of Yuenmingyuen (literally "residence of the original splendor") contains a little of everything—isolated palaces, temples, pavilions, pagodas, pyramids, porticoes, colonnades, artificial mountains, grottoes, lakes, rivulets, islands, groves, labyrinths, observatories, and kiosks. The artificial rock work, so fashionable among us a few years ago in Paris gardens, is here—immense, striking, monumental, and unique.

Here, for instance, is a mountain built up of rocks; in niches cut in its sides are images of all sorts of infernal divinities, who grin and squirm in the midst of unheard of vegetation. It dominates the entire park, its summit is crowned by a little pagoda, about 25 feet by 20, surmounted with roofs entirely of white porcelain, decorated with stars; it is dedicated to the Chinese Virgin; Koua Him, who, from this culminating point, seems to extend her protection over all the palaces lying at her feet. She is represented by a statuette of gilded bronze, seated in the midst of a lotus flower; on each side watches a fully armed warrior; these two sentinels are engaged in hideous contortions and in making horrible faces.

On the right of this artificial mountain, following a labyrinth whose tortuous paths easily lead one astray in a space of 50 square yards, rises a large building; it is the imperial library. Its roof, with yellow tiles, resembles that of the throne room, and like it is peopled with a menagerie of black faïence dragons chasing other chimerical monsters.

The hall, 40 feet high, 30 wide, and 120 long, has its walls lined with cases in which are most curious and ancient manuscripts. In the hall are tables and armchairs for studious visitors, and two small altars, one to the north and the other to the south, on which are still slowly burning perfume incense sticks in honor of Confucius and of Lao-Tzeu, whose portraits are reproduced on large silken banners suspended here and there.

Here are the grottoes, deep, crooked, and full of statues of gods and animals; some have the entrance curtained by hanging vines; in others a crystal cascade falls from an upper basin and loses itself murmuring through the turf. Here are the lakes; in the center of the largest is a small palace, which we have neither the time nor courage to visit, but which I beg the reader to keep in mind; he will soon learn why. This palace, built on an island, whose heaped-up soil scarcely rises above the surrounding water, seems to emerge from the bottom of the lake.

On the border of the lake, to the left, is a large building of carved and precious woods, entirely smothered under the vines twining around it, climbing its top, and winding in flowery plumes about the tails of dragons scaling its roof. It is a coach house, and contains the carriages of gilded and carved wood, with doors covered with Vernis Martin, interiors lined with Genoa velvet, great carriage lamps of chiseled silver, with thick and heavy cloths like women's dresses at the court of Louis XIV, and ornamented with pendants of gold and of silk—which had been sent to the Emperor of China by George III, through Lord Macartney, at the end of the preceding century. In this memorable embassy, the English, with the object of serving the interests of the East India Company, consented to pay tribute to the Emperor of China. These carriages, their magnificent trappings stretched on wooden horses, were never used; they were covered with dust and could not have been often seen.

Alongside of the stable was the landing place of the imperial pleasure boats, its roof of yellow tiles extended above the lake. There was the bark of His Majesty, one for the Empress, others for royal princes, and still others for high mandarins. There was the fishing boat of the Emperor, gilded and lacquered, and still furnished with his paraphernalia. Within this the Son of Heaven gave himself up to fishing among the innumerable varieties of fish which the Chinese fish breeders, foremost in the world, had created for him, but he can not have abused this sport, for the fish appeared to us to be quite tame, and as they had no patriotic spirit, they came to the edge of the lake to gaze at the barbarians and shamelessly ate their bread. There are gold-fishes a foot long, whose name alone describes them. Here are redfish, cousins to those that people the basins in the Tuileries, and here are little marine monsters, all head, with eyes as large as those of a man; while others resemble the sea-horse, a fish venerated by the Chinese under the name of water dragon; to us they are hideous, but to them beautiful.

A little farther on rises a tower, an exact reproduction of the famous porcelain tower of Nankin, its numerous roofs marking as many stories. To reach it one has to pass in front of a pagoda built in honor of Buddha; and the statue of the god seated on a low pedestal, his legs crossed in Turkish or Chinese style, is not less than 65 feet high, while a staircase which runs along the interior wall of the pagoda permits climbing to the level of his head of frizzled hair, his knees being reached at the first story, his navel at the second, and so on. This very ancient statue is of gilded bronze, but time has impaired the gilding; the half-closed eyes of the god are of silver, their pupils of iron; from one knee to the other at the base the statue measures 45 feet. Two gigantic incense burners and one altar are in this pagoda, which has been constructed solely as a shelter to the statue.

Our presentation to this enormous gentleman terminated our visit to the summer palace. It had lasted several hours. We returned worn-out, exhausted, our eyes burning from the sight of all this gold and this splendor, with aching heads.

The general in chief placed sentinels at all the entrances to prevent anyone from penetrating the palace before the arrival of our allies, and he assigned two captains of artillery, MM. Schelcher and de Brives, to see that the order was strictly carried out.

To add to the effect of our signal guns, Brigadier Pattle had sent numerous troops of cavalry in every direction, who finally met General Grant with his army and brought them in at noon. On his arrival General Grant went into the palace and saw with his own eyes that everything was intact.

PILLAGE OF THE SUMMER PALACE.

I reach here a delicate point in the history of the campaign in China, an episode of which the whole truth has never been told. I will relate this episode with absolute frankness; at least. I will try to do so.

The summer palace was pillaged and partially burned. Who is responsible for this pillage and burning? Could they have been avoided? Was this pillage contrary to the laws of war? Who profited by it? Did either one of the allies take advantage of the other? Here are plenty of questions, I simply state the facts and briefly discuss them, and after having read this chapter the reader may answer them himself.

The generals had decided in concert that a committee of six, three from each nation, should be named and appointed to select the most precious objects, considered in their intrinsic and artistic value, so as to have an equal division. The commission immediately commenced its labors, and the removal of the most valuable articles, at least those apparently so, was systematically begun, and the first examination of the palace led to the discovery of treasure valued at about 800,000 francs in small ingots of gold and silver. This sum was divided between the two armies and, when subdivided exactly, it formed for each man a prize of about 80 francs.

It was nearly in the middle of the afternoon and the sentinels had been continually on guard, gun in hand, before the palace within which the commission was working. Every few minutes soldiers marched out laden with bric-a-brac which excited the admiration of the troops gathered before the sentinels. After laying down their burdens these soldiers returned and showed their passes.

In the midst of the troops of all sorts who took part in this first move, French infantry, Englishmen, unmounted cavalry, artillerymen, Queen's dragoons, Sikhs, Arabs, Chinese coolies, all mixed together, a rumor circulated and spread, repeated in all the idioms represented by the crowds assembled there, with their eager eyes and their mouths dry with desire. They said, "When most has been carried out we shall enter and have our turn; why the devil should we not have at least our own slice off the cake? We have come far enough. Isn't that so?" And they laughed and nudged each other. A little disorder had already begun.

General Montauban, who began to feel anxious, was walking about at the other side of the square, leaning on a green bamboo which replaced the walking stick that he lost in the panic of the night before, but things had not reached such a pass as to require interference.

Suddenly a trumpet call resounded, a company was called to arms. What could it be? A very simple thing; the Chinese of Haitien had entered the park by scaling the walls, and it became necessary to protect the treasures which were just being explored.

"It is too bad," said the troopers; "these Chinese are going to grab everything. We must see about that."

The peasants of the neighborhood and common people of Haitien were slipping up to the walls of the park; they fraternized with our coolies and chatted with them. Our coolies had ladders which they placed against the walls and, like a great crowd of sparrows, the black-headed pillagers filled the avenues and ran toward the palace.

It became necessary to disperse them and for this purpose a company was called to arms. It had not yet assembled when a second trumpet call was heard; this was for another purpose; it called for soldiers without arms, equipped as a fire brigade, for partial attempts at firing had already begun.

In China when a fire breaks out, before thinking of protection from the flames, it becomes necessary to seek protection from thieves who arrive at the points threatened quicker than the firemen, and the result is that the habitual robbers who profit by fires know how to start them and consider the fire as a necessary ally, and an element indispensable to a good stroke of business.

Consequently, the Chinese of Haitien and our coolies had brought torches and bundles of straw—in fact, everything that was needed to burn a palace—and had immediately undertaken to exercise their special industry.

The trooper, on hearing these facts, which reached him magnified and exaggerated, felt his anxiety give place to anger; awhile ago he thought, "These Chinese will cabbage everything;" now he added, "The rascals are going to burn everything."

Irresistible pressure at the guarded gates carried away the sentinels, the crowd rushed in, together with the company under arms and the workmen who had been summoned; and immediately each one laid hold of that which best suited him and carried it off. From the very first moment I noticed the characteristics of the two allied nations: the Frenchmen went each for himself; the Englishmen, more methodical in their ways, had instantly comprehended the business in hand and systematized the pillage.

They arrived in squads, like gangs of workmen, with men carrying large sacks and commanded by noncommissioned officers, who brought with them, strange as it may seem, touchstones. I do not know where in the world they found them, but I can state that they possessed this primitive jeweler's tool.

Englishmen, Frenchmen, officers, and soldiers had entered the palace with the inhabitants of Haitien, with our coolies, who fiercely hated the northern Chinese—pellmell with the crowds of parasites who follow armies like crows, dogs, and jackals.

To ask our men to let this human torrent flow by them while they stood still was asking something beyond human power. They were like the dog in the fable carrying the dinner of his master, who began by defending it, but when he saw another had got a bite he seized his own share. Our men entered like them and along with them. What could the General or his officers do? Absolutely nothing. If they had tried to stem the torrent they would have been swept away by the rush; they would have compromised their influence and reputation, and with it the future of the expedition. With us, as with the English, the generals had only one thing to do, to shut their eyes. It was one of those psychological moments in military life when, as Count von Bismarck said later, the artificial regulations which serve to bind nations as well as armies disappear, leaving primitive human nature in all its crudity and absolute surrender to its free instincts. Such moments occur at two points in the history of armies—in overwhelming defeat and in supreme victory; and at such times there are no longer regulations or authority. Men become purely selfish, either in the depression of a disaster or in the intoxication of triumph.

Under these conditions the commanders must be prudent and patient, they must stand by and wait until the fear of defeat or the fatigue of victory brings once more around them their human flock, who are soon dismayed at not feeling upon forehead and shoulders the accustomed yoke, and will come of their own accord to take it up again.

Montauban, with all his energy, could no more have prevented his troops from passing through the great gate of the summer palace, than Napoleon, with the prestige of a demigod, could have stopped his armies flying from the field of Waterloo; accordingly he remained in his tent, equally abandoned by his men, while General Grant remained in his own, and both did right.

Lord! I do not wish to make myself out better than I am. I never set up for an angel for fear I should pass for a fool, and I admit that I could have taken my share of the treasures of the Son of Heaven without any scruples. I even think that I might have stuffed my pockets a little fuller than most of my comrades, because I had an advantage over them in a more perfect knowledge of the value of the articles and in the habit of a collector, which would have assisted me in choosing the most precious and the least cumbersome. It was self-interest that held me back; for living in close relations with the General, eating with him, leaving him scarcely more than did his shadow, I could not hope by any device to hide from him my booty. Besides, I saw that he was distressed at what was taking place, and I did not wish to increase his displeasure. And why didn't I wish to give him trouble? In the first place, because I loved him; but, secondarily, because I knew that there was destined for me in his hands a little thing, my cross of the Legion of Honor, which had been promised me. Now to have the cross at twenty seemed to me something that I would have gone through the fire for. As to the riches of the summer palace and its golden pagodas and diamonds, the Emperor might have them, the others might take them.

Oh, youth! Oh, brave days when I was twenty! Oh, illusions! Oh, dreams! How good it all is, even when you are fooled by it!

I was simply an onlooker, a disinterested but curious spectator, and I enjoyed this strange, unforgetable vision. There was this ant-heap of men of every color, of every race, this entanglement of individuals from every nation on the earth, swarming on this mound of riches, hurrahing in all the languages of the globe, hurrying, struggling, stumbling, falling, picking themselves up, swearing, cursing, exclaiming, while each carried off something. I say it looked like an ant-heap, crushed under one's foot, where the terrified workers fly in every direction, one with a grain of wheat, another with a bug, another with an egg. There were troopers, their heads buried in the boxes of red lacquer belonging to the Empress; others, half smothered in the folds of brocades and of pieces of silk; still others, who had placed rubies, sapphires, pearls, and rock crystals in their pockets, in their hats, in their cloaks, and who hung around their necks strings of great pearls.

Others carried off clocks and dials in their arms. The sappers of the engineers had brought their axes and broke up the furniture to secure the precious stones with which they were incrusted. There was one smashing a lovely Louis XV clock to secure the face, on which the hours were marked with crystal figures, which he mistook for diamonds. Now and again the cry "fire" was heard. Everybody rushed out, letting everything fall, and extinguished the fire, which was already licking the precious wall, by heaping on it silks and damascenes and furs. It was like the dream of a hashish eater.

And when, after passing through the apartments given over to pillage, I emerged in the park, the spectacle of nature in its eternal tranquillity made me shudder on coming from this furnace, like a cold plunge as we step from a Turkish bath. Here and there in the park were groups running toward the palaces, the pagodas, and the libraries. Alas!

But the great lake was silent, deserted; its aquatic palace and its row of gondolas abandoned.

"I am going to see what there is in there," said I to myself, looking at the island. I jumped disrespectfully into the imperial gondola, lacquered on the exterior, and lined in the interior with yellow silk, like a glove box, and I set myself to sculling energetically toward the palace, which I shall not describe, first, because it was exactly like all the others I had seen, and, secondly, because the reader must be wearied with descriptions already.

I leaped ashore, fastened my boat to a carved post, and, mounting three steps of white marble, I entered the principal room, entirely surrounded by sofas made of large cushions covered with yellow damask and resembling Turkish divans.

I inhaled the air, which smelled very sweet, too sweet to have been subjected solely to the breeze from the lake for two entire days. With my hand on my saber I listened, for I thought I heard half-smothered sighs. I examined the yellow cushions, and they had suspicious humps. I kicked one off; a sharp cry rang out, and a woman suddenly appeared, crouching on the ground like a little rabbit, costumed in those delicate and costly hand-embroidered silks that are made for ladies of high rank. She stood at the foot of the bed, prostrating herself, bowing until her forehead touched the earth, showing only her black hair, secured by golden hairpins.

If you have never seen a man in an embarrassing position, imagine me, standing up there, my hand on my sword, and this woman at my feet.

To induce her to rise, I contented myself with saying in Chinese, "Have no fear; I will do you no harm." She rose on her two little feet, a lovely creature, twenty years of age, dressed like an empress.

As no cry from the pretty child had as yet indicated that she feared for her life, the humps of the other mattresses began to increase in size. Heads of women began to appear, and little by little their bodies, and a small crowd surrounded me, beating the matting with their pretty foreheads. There were twenty-seven women.

I had lit upon the harem, or at least a portion of the harem, of His Majesty. Oriental people are accustomed to construct the apartments of the women on islands; and here I was with twenty-seven women on my hands, and so beside themselves that when one emitted a sigh or a groan all the rest fell to the ground, supposing that another barbarian had arrived, and wishing to show him the same marks of respect, of fear, and of submission.

I had a great deal of trouble to soothe them, and to prevent them from suffocating themselves. They had had, I may venture to say, the good luck to fall into the hands of a gentleman, but it was not to be supposed that during the night and the day following they could escape the investigations of our soldiers who were still occupied in the interior of the palace, but who would not fail to emerge and rob in every direction as soon as the principal buildings had been sacked. The island would have been a mouse trap for them. I decided to ask them if they would leave and seek safety in flight, no matter where.

"Yes, yes, yes," they all cried.

And then down they went again, foreheads on the ground, as if they wished to salute the matting.

I took nine of them and made them sit down in the imperial gondola, which would carry no more, for the water trickled over its sides. I begged them to keep still, and I pushed my boat into the lake, not in the direction of the landing place, but straight for the stable containing the carriages already described, the roof of which hid us from the summer palace, and consequently prevented those who filled it, and were otherwise much occupied, from troubling themselves about us.

I led the women into the stable, and I piled them on the dusty cushions of King George's carriages, which for the first time were rendering some service to the Emperor of China. I cautioned them to keep still, and returned for a second load of nine women, and afterwards for a third. On this last trip, while steadily sculling, I commenced to ask myself what I should do with them all, and if I should not have better left them to their chances rather than to bring them out perhaps into imminent danger, for I did not know how far the French, the English, the Hindus, and the Arabs could be trusted.

Just as I landed and drove the last convoy into the stable, I saw quietly installed in one of the immense carriages, filled with the women, a trooper, a sergeant of the line, before whom all their terrors had returned.

"What are you doing there, comrade?" said I.

"What are you doing yourself?"

I gave free vent to my wrath.

"I am the secretary of the general in chief, and if you move an inch, or if you touch one of these women with the end of your finger, I will break your head! If you are not satisfied I will begin now. Clear out!"

"You ought to have told me at once that you were the General's secretary," replied the sergeant, leaping from the royal carriage.

The trooper had a pleasant mien, a blue eye, light hair, well-trimmed head, an air of discipline, and was not ugly in his bearing.

My title of secretary to the general in chief had produced a magical effect. I regretted having threatened him with it, and stretched out my hand to him, saying:

"I beg your pardon, comrade, but you know I have instructions. Orders! Orders!"

"I understand perfectly," he said, with the air of a man who does not understand anything. "We are to save these individuals."

"They are the wives of the Emperor," said I, raising my hands with an appropriate expression.

"The devil! Can I be of any assistance to you?"

"Yes; help me to get them out of this park."

"Where shall we take them to?"

As I had absolutely no plan, I answered peremptorily, "We shall see."

"I was about to propose, if you please, that we should take them to a Christian, who lives near by at Haitien. I got acquainted with him this morning, because he came to see the paymaster, who is my friend and countryman, and we went together to take tea with him. He is a fine fellow."

"Let us go to your Christian, my friend, but Orders! Orders!"

"All right."

On our left, near the carriage house, a park gate opened into the country. There we led the women. They hobbled along on their little mutilated feet like birds from which the large feathers of their wings had been clipped. Most of them had covered their brilliant toilets with long, loose wrappers, so as to look like peasant women, but through the slits of the gowns escaped the billows of silk, and little slippers of red satin peeped out like doves' bills from these sumptuous parcels. It was charming, on the green grass they seemed to me like a cluster of living flowers.

THE NIGHT IN CAMP.

When I returned to the camp night was falling. The men came back loaded with booty, bearing the most heterogeneous collection of articles, from silver saucepans to astronomical telescopes and sextants—a prodigious mass of material which they certainly could never carry home.

The English camp filled up in the same way, but there everything was carried on in perfect order. In our camp the soldiers were masquerading. The artillerymen arrived enveloped in the garments of the Empress, their breasts decorated with the collars of mandarins. Over there the articles had been placed in piles in each tent, and they had already begun to sell them at public auction.

Just here I must relate a little anecdote. One of our spies, my orderly Mohammed, was extremely attached to me, both through affection and by interest.

"You are the friend of the General," he often said to me. "You put words into his mouth; you must get me a medal."

When he returned from the summer palace he brought a double handful of pearls.

"These are for you," he said to me, simply.

And thus it happened that I, to please the General and to secure the cross of honor, had seized nothing, while my spy, to give me pleasure and to secure a medal, had plundered on my behalf; the same motive had inspired both of us to quite contrary acts.

"Thanks, my lad," said I to him, "keep all that yourself; it is probably worth a great deal."

"What will you take for your pearls?" said one of my comrades, who stood by.

"Give me a bottle of brandy."

"Agreed."

And Mahommed gave him his pearls.

A bottle of brandy in the camp at Yuenmingyuen was sold to us by the sutlers for 100 francs. After the expedition to China was over the pearls were sold for 35,000 francs.

I notice here another curious thing, and one which ten years later was confirmed by the soldiers of Emperor William.

Nothing tempts soldiers like clocks and other objects containing mechanism. Now, the Chinese, like all oriental people, and like all people with whom machinery is still in a rudimentary stage, greatly admire mechanical articles, especially of the amusing kind. From time immemorial our sovereigns and officers of customs have turned this mania to good account, and have sent or taken to them all the curious inventions of opticians, of toy makers, and of manufacturers of automatons. It will never be known how many musical boxes, toy organs, clocks with complicated chimes, alarm clocks, rabbits with tambourines, panoramas, clocks turning windmills, crowing cocks, climbing monkeys, singing birds in brass cages standing on pedestals which are wound by turning a key, mechanical flute players, monkey violinists, trumpeters, players on the clarionet, and even whole orchestras of monkeys seated on an organ, little tight-rope dancers, waltzers, and so on, were found in the summer palace. The rooms of the Empress and of the women were literally overflowing with them.

Part of our soldiers were wide-awake and part were but overgrown children; the latter in the majority. The clever ones had supplied themselves with jewels, the coined money, and the dollars, bonbonnieres, snuffboxes, dishes of gold, and collars of pearls. The others had been principally tempted in the midst of unheard-of riches by these mechanical toys of European origin, all of which had been most generously left them by the Englishmen.

Therefore, the second night that we passed near the summer palace was exciting, insensate, head-splitting. Each trooper had his bird, his music box, his monkey, his clock, his trumpeter, or his rabbit. The clocks struck continuously, in every tone, at all hours, now and then accompanied by the sad snap of a spring broken by inexperienced hands. Multitudes of rabbits playing on their tambourines formed a bass, accompanied by the cymbals of monkeys playing four thousand waltzes and quadrilles, together with as many music boxes, which dominated the cuckoo clocks, the sweet notes of the flute, the nasal notes of the clarionets, the screeching of the cocks, the notes of horns and cornets, as well as the hearty bursts of laughter coming from the easily amused crowd.

It was a nightmare.

At sunrise the plundering began again. In front of the tent of the general had been placed one of the two pagodas of massive gold found in the Emperor's oratory; it was destined for Napoleon III. The other had been secured by the English. On the top of this pagoda an enormous diamond scintillated. It was guarded by two sentinels. It had not stood there two hours before the great diamond had disappeared. It was never known who had taken it.

The pillage of the summer palace lasted two days. Toward the close of the second day General Montauban, to stop it, adopted an ingenious scheme. He walked into the midst of his soldiers, who were disguised as mandarins and imperial princesses, and said:

"Boys, leave all those things alone; you can't carry them off. And what would you do if we should encounter the enemy, and they should beat us? Believe me, we are going to Pekin, and there will be things enough there for everybody. You will see."

I heard him make this little speech to an artilleryman who, being convinced, threw to the ground that which he was carrying in his arms, tore off his fancy costume, and resumed his uniform.

The artillerymen, on this occasion, it must be admitted, had the largest share, for they had the use of horses, caissons, and the wagons. They made use of every corner of the caissons, and when they were full they filled the buckets in which the rammers were plunged to clean the cannon shot.

This little address of the General, however, with its pious fraud, usually produced an effect, and nearly all the soldiers imitated the artilleryman.

The summer palace was sacked for forty-eight hours. Now, I want, in a philosophical parenthesis, to ask myself whether these acts, so impossible to repress or prevent, were so extraordinary as to constitute a novelty; were they consonant with international law; or were they contrary to the laws of war?

When two workmen fight with knives, when two gentlemen face each other on the field with their swords, when two nations put themselves in battle array, with cannon and bayonets, the workmen, the gentlemen, and the nations obey a common instinct which causes man to destroy his enemy in any way he can.

In the first case, however, the conqueror is inexorably condemned as a murderer by the courts; in the second, he is scarcely punished, and if he had refused the combat the same judges who would have condemned him for having fought would find fault with him for shirking the encounter. In the third case the conquered is said to be an unfortunate and estimable hero; the conqueror is crowned with laurel, applauded by men, loved by women, and adored by the people.

Human life is then only to be respected in certain circumstances, and its destruction is reprehensible only in certain cases, determined by the judgment of the world.

The same rules apply to property. A man who takes a loaf of bread from a baker's shop is a thief; the nation that take five thousand million of francs from another country is a great nation. If I, an enthusiastic lover of objects of art, should take from the cabinets of the Louvre a little bronze statuette, I should promptly be placed in custody; but if I should enter Italy at the head of an army and carry off the treasures of the museums I would immediately be hailed emperor of the French.

Hence we see that public and private property is considered in two different ways. It follows that in China we had the incontestable right to seize and to carry off all the articles of great value belonging to the nation—that is to say, to the Emperor—with whom we were at war, just as the Germans had the right to take from us our millions; as Bonaparte had the right to seize in conquered Italy the works of art. Consequently, the pillage of the summer palace was lawful, as lawful as could well be, because it was accomplished in time of war.

The principle can not be disputed; the only error committed was one of detail; we did not simply pillage; we wasted and squandered, and the latter is more blameworthy than the first.

In my opinion, this is how the thing should have been carried out if it had been possible to control our men: All the riches of the palace, as well as those of the palace of Pekin, should have been taken out and packed up and divided between the two victorious nations; all things suitable for a museum should have been set aside, the rest should have been sold, and the proceeds devoted to compensating the soldiers of the expedition, or to lightening the taxes and appropriations; we should have imitated, in fact, that which the Prussians in France, and before them, Napoleon, had carried out in Italy.

Had we proceeded in this systematic way, no one could have made any objections, excepting philosophers, dreamers, and people who insist upon comparing war to an assassination and its booty to the fruit of robbery.

But this was not done, nor was it possible. I admit that my heart bled on seeing, for instance, the space which separated the palace from our camp covered with silks and precious fabrics trampled in the mud – goods worth twenty millions; on seeing a soldier light his pipe or heat his pot with a vellum of beautiful and unique manuscript; on seeing, at our departure, magnificent timepieces, masterpieces of the watchmaker's art, engraved ivories, thrown into the trodden paths over which rolled the wheels of wagons and of caissons; on seeing the lightly built and magnificent edifices destroyed by ruthless flames.

Speaking of carriages, here is a curious fact: On arriving at Haitien the French army had but a single wagon, belonging to the general, carrying his tent, dinner service, and cooking utensils; when the army left they had unearthed such a number of well-loaded army wagons that it took them an hour to pass by. The baggage wagons of the English stretched out in an exceedingly long line, and the fantastic procession covered at least two leagues of country.

Behind us followed the Chinese, still insatiate, carrying away the poor remains of our plunder. The unlucky fellows could not carry them into Paradise, as the saying is. After the expedition was over the Tartar soldiers of the Emperor returned to Haitien; and houses and fireplaces were closely searched, all of value was carried back to the palace, and those who stole the precious objects perished by the sword.

I perceive that I have not made the most of one circumstance extenuating our excesses—the exasperation of our soldiers at the massacre of many of their comrades who had been surprised and taken prisoners at Tangtcheou.

At Yuenmingyuen, behind the throne room, was found the uniform of Colonel Foulon de Grandchamp, his notebook, the saddle and bridle of M. Ader, superintendent of hospitals, many articles which had belonged to the English officers, and 15 complete uniforms of the Sikhs. All these things had been brought to the Son of Heaven in order that he might gloat over these relics of the barbarians.

On discovering these proofs of the horrible fate of our brothers in arms, the soldiers raised cries of rage. Had they encountered ten palaces like that of Yuenmingyuen, they would have sacked them and burned them with pleasure.

We quitted the summer palace on the ninth—a cold, damp day. The buildings containing the imperial apartments, the reception hall, and the throne room were ruined, but the palaces, pagodas, and library were intact. We went on toward Pekin and had hardly marched an hour when two English officers came to announce to the general that the Chinese had sent five of our prisoners—M. de Lauture and four soldiers—into their camp.

I was directed to follow the officers and bring our countrymen back, and found them in a most dreadful condition—M. de Lauture particularly. His height seemed to have shrunk by a foot. He was clothed in the gown of some old Chinese woman, covered with mud. His hands were bound up into the form of an S. They had been tied with cords which sunk into the flesh and which had been constantly wet, when he complained, in order to cut in more. Besides which he had been horribly mutilated, and it was while he was suffering this martyrdom that Prince Kong, the brother of the Emperor with whom we were treating, wrote to Baron Gros: "I have the honor to inform your excellency that I have given orders that the interpreter of your noble Emperor—M. d'Escayrac—should be treated with respect, and that my intention, after having regulated in a pleasant way with him everything relating to the signing of the convention, shall be to return at once and in a proper manner your other compatriots." And there are people who still say that we acted in China with a certain want of decorum!

The companions of M. de Lauture, with the orderlies of Captain Chanoine and Subintendant Dubut, named Rosel, Bachet, Génestet, and Pelet, were separated from each other during their tortures and they could only speak of what they had themselves seen. They were ignorant of the fate of their martyred colleagues, but it was established by the statements of the prisoners who were returned to the English that the greater part were dead of their wounds.

Mr. Norman, the first secretary of the embassy of Lord Elgin, his head opened with a saber cut and abandoned, tied hand and foot, died with his brains destroyed by the worms. Mr. Bowlby, the correspondent of the *Times*, was thrown from a window into the court, where he was devoured by the pigs.

[A portion of the treatment of these people, as given by our author, is too horrible for quotation.]

I have already said that nothing can give an idea of the Chinese imaginations when torture is in question. Thus during this same march on Pekin, and this same day, I saw some roving dogs disputing bits of flesh which they were digging up with their paws and devouring. We drove them away and found that their food was the remains of five coolies from our own forces, whose numbers were recovered from the bits of their blouses. The Chinese had buried them alive upright, bound, but with the head alone exposed, and the dogs had come and begun by licking their faces, then by biting, and then by eating off their heads.

In a village 4 kilometers from the walls of Pekin, the European prisoners were finally returned both to the English and to us. "We are bringing them all back to you," said a little mandarin who preceded the carts, and we saw these specters in the coffins together, for they had conscientiously returned to us the remains of those who had succumbed to their tortures. All the coffins were opened and the identity of the putrid remains was established. In all, the Chinese had taken at Tangtcheou 26 of the English and returned 13 alive and 13 dead; they had taken 13 French and returned 6 alive and 7 dead.

[The Comte D'Hérisson pursues this horrible subject further and gives ample evidence of the truth of what he states. It is not necessary to quote here more than we have done, but we may add that the allied forces decided after this to return and destroy the summer palace, though, as has been said, the immense scene of plunder we have described took place before these aggravating circumstances were known.]

PROGRESS OF MEDICINE IN THE NINETEENTH CENTURY.[1]

By Dr. John S. Billings, U. S. A.
Director New York Public Library.

The word "medicine," as used in the title of this paper, includes all branches of the art of prevention and treatment of disease and injuries; all discoveries of methods of diminishing physical pain and of prolonging life, and also that part of modern science which is concerned with accurate knowledge of the structure and functions, normal and abnormal, of the human body, and of the causes of disease. In other words, it includes not only therapeutics, medical and surgical, but also physiology, pathology, and hygiene.

In all these branches of medicine greater progress has been made during the last century than had been made during the previous two thousand years. This progress has been largely due to improvements in methods of investigation and diagnosis, resulting from increase of knowledge in chemistry and physics; to better microscopes and new instruments of precision; to experimental work in laboratories, and to the application of scientific method and system in the observation and recording of cases of disease and of the results of different modes of treatment. The introduction of statistical methods in the study of cases of disease and of causes of death; the discovery of general anæsthetics; the adoption of antiseptic and aseptic methods in surgery, and the development of modern bacteriology, each marks a point in the history of medicine in the nineteenth century.

The scientific demonstration that some diseases are due to the growth and development of certain specific micro-organisms in the human body dates from about twenty years ago, although the theory of such causal relation is much older. Since 1880 it has been proved that anthrax, Asiatic cholera, cerebro-spinal meningitis, diphtheria, one form of dysentery, erysipelas, glanders, gonorrhea, influenza, certain epidemics of meat poisoning, pyæmia and suppuration in general, pneumonia, tetanus, relapsing fever, tuberculosis, bubonic plague, and typhoid fever are due to minute vegetable organisms known as bacteria; that malarial fevers, Texas cattle fever, and certain forms of dysentery are due to forms of microscopic animal organisms known as

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microzoa; and for most of these diseases the mode of development and means of introduction of the micro-organism into the body are fairly well understood. To the information thus obtained we owe the triumphs of antiseptic and aseptic surgery, a great increase of precision in diagnosis, the use of specific antitoxin as remedies and as preventives, and some of the best practical work in public hygiene.

The evidence as to the increased powers of medicine to give relief from suffering and to prolong life is most clear and direct in the records of modern surgery—particularly in some of its special branches. In a large proportion of certain cases in which the surgeon now operates with a fair chance of success, such as calculus in the kidney or gall bladder, shot wounds in the abdomen, and tumors of various kinds, there was no hope in the year 1800, and the unhappy sufferer could only expect a certain, though often a lingering and painful, death. In cases of cancer of the face, tongue, breast, or uterus, the persistent pain, extreme disfigurement, and offensive odors which attended them made death a boon to be prayed for, if not deliberately sought, while now such cases, if brought in time to the surgeon, can often be entirely relieved. The knowledge of this fact has become general with the public, and patients no longer defer an operation as long as possible, as was their custom in days of old. Instead of having to look forward to the torture of incisions, manipulations, and stitching, with but small hope of surviving the exhausting suppuration and blood poisoning which were such common results, the patient now knows that he will inhale a little sweet vapor, and sleep unconscious of the strokes of the surgeon's knife or the pricks of his needle. He may dream wondrous dreams, but will soon awake to find himself in his bed staring at his trained nurse standing by his side, and wondering vaguely why the operation has not begun. He does not have to look forward to weeks and even months of daily dressings. The surgeon will glance at his temperature record and at the outside of his bandages, but will probably not touch them for a week; and when he does remove them there will be nothing to be seen but a narrow red line without a trace of suppuration. These improved methods not only preserve the mother for her children, and the bread winner for the family, but they greatly contribute to the public good by shortening the period of enforced idleness and unproductivity after operations.

Some of the greatest triumphs of modern surgery are obtained in cases of disease or injury of the abdominal organs. The removal of ovarian and uterine tumors is now so common and successful that it is not easy to realize that a hundred years ago there was practically no help or hope for such cases. In former days the lists of deaths contained many cases reported as inflammation or obstruction of the bowels, or as peritonitis. It is now well understood that most of these cases are due to disease of a little worm-like appendix connected with the large intestine on the right side of the lower part of the abdomen, inflammation of which, known as appendicitis, causes excrutiating pain and often produces internal abscesses and death. An operation for the removal of such a diseased appendix is now common, and, in most cases, successful. The operation for the removal of calculus or stone from the urinary bladder dates from over two thousand five hundred years ago, and no one knows who first performed it. Within the last century it has been largely superseded by an operation which crushes the stone to powder within the bladder, and removes this powder without the use of the knife. The removal of calculi from the kidney, or from the gall bladder, and the removal of a diseased kidney are new operations, made possible by improved means of diagnosis, anæsthesia, and antisepsis. Wounds of the intestines were formerly thought to be almost necessarily fatal, and nothing was done for them except to stupefy the patient with opium. Now, in such cases, the abdomen is opened, the lacerations of the bowel are closed, the effused blood and other matters are removed, and in many cases life has thus been preserved.

By increase of knowledge of the anatomy of the brain, and of the distribution of nerves connected with it, it has become possible in a certain number of cases to determine what part of the brain is suffering from irritation or pressure, and to operate for the removal of the tumor or other substance causing the trouble, with considerable hope of giving permanent relief. A branch of surgery which has developed into an important specialty during the last century is that known as plastic and orthopædic surgery. The replacing of a lost nose by engrafting other tissue in its place is a very old triumph of surgical art, but operations of this kind have been greatly extended and perfected within the last hundred years, and much can now be done to mitigate the deformity and weakness due to club feet, bandy legs, contracted joints, etc., which formerly were considered to be beyond remedy.

Many of the diseases peculiar to women have been deprived of much of their terrors within a hundred years. In 1800 for every thousand children born, from ten to twenty mothers died. Puerperal fever occurred in epidemics, following certain physicians or nurses, but nothing was known as to its causes or nature. To-day puerperal fever is almost unknown in the hospitals or in the practice of a skilled physician. The death rate of mothers is less than five per thousand births, and the mechanical obstructions which a century ago would have almost certainly brought about the death of both mother and child are now so dealt with that more than half of both mothers and children are saved.

The study of the diseases of the eye has greatly developed another specialty during the century, viz, ophthalmology. The investigations of Helmholtz in physiological optics, with his invention of the ophthalmoscope in 1852, effected a revolution in this branch of medical science and art and have added greatly to human comfort and happiness. A hundred years ago, when the physician saw the eyelids of the newborn babe redden and swell and yellow matter ooze from between them, he knew that in a few days or weeks the child would be partially or wholly blind, but he knew nothing of the simple means by which the skilled physician can now prevent such a calamity. It is unfortunately true that this knowledge is not even now sufficiently widely diffused and that our blind asylums must, for some time to come, continue to receive those who have been deprived of sight during the first months of their life through the ignorance or neglect of those who should have properly cared for them.

While it is certain that the death rates in the last century were greater than those of the present day, it is not possible to make precise comparisons. The record of deaths in the city of New York begins with 1804, and was necessarily very imperfect until the law of 1851, which required the registration of all deaths; but it shows a death rate of 30.2 per 1,000 in 1805, which means that the true death rate must have been between 35 and 40. At present, for a series of five years, it would be about 20, having been below 19 in 1899, so that the death rate has been diminished by at least one-third. How much of this is due to improved methods of treatment, and how much to improved sanitary conditions, it is impossible to say. A comparison of the list of causes of death in 1805 with the list of causes for this year shows great differences, but much of this is due to changes in name and to more accurate diagnosis.

"Malignant sore throat" and "croup" were well known to anxious parents in 1800, but "diphtheria" caused no anxiety. "Inflammation of the bowels" was common and fatal, but "appendicitis" had not been heard of. Nervous fever, continued fever, and low fever were on the lists, but not typhoid, which was not clearly distinguished as a special form of disease until 1837, when Dr. Gerhard, an American physician, pointed out the differences between it and typhus, which also prevailed at the commencement of the century.

One hundred years ago the great topic of discussion in our cities on the North Atlantic coast was the means of preventing yellow fever, which had been epidemic in New York and Philadelphia for two years. Physicians were disputing as to whether the disease was contagious and imported, and therefore perhaps preventable by quarantine and disinfection, or was due to some occult condition of the atmosphere (which was the view taken by Noah Webster in his history of epidemic and pestilential diseases, a work which appeared about the middle of the year 1800, although it is dated 1798). The discussions remind one of the remark that a certain patented form of electric light was surrounded by a cloud of nonluminous verbosity. For example, the committee of the Medical Society of the State of New York reported that yellow fever may be produced in any country by pestilential effluvia; and Webster concluded that typhus and nervous fevers were due to a "conversion of the perspirable fluids of the body into septic matter"—all of which means that they knew nothing about it. Even now we do not know the cause of yellow fever, or the precise mode of its spread; but we are sufficiently certain that it is due to a specific micro-organism to be confident that its spread can be checked by isolation and disinfection properly applied—and Memphis and New Orleans are witnesses of the truth of this.

In the year 1800 the majority of persons over 20 years old were more or less pitted by smallpox, being the survivors of a much greater number who had suffered from this disease. Dr. Miller in New York had just received from England a thread which had been steeped in the newly discovered vaccine matter, and was about to begin vaccination in that city. To-day there are many physicians who have never seen a case of smallpox, and a face pitted with the marks of this disease is rarely seen. During the century there have appeared in civilized countries two strange and unfamiliar forms of epidemic disease, namely, Asiatic cholera and the plague, the first coming from the valley of the Ganges, the second from the valley of the Euphrates, and each having a long history. A really new disease was the outbreak in Paris in 1892 of a specific contagious disease transmitted from sick parrots, and known as psittacosis. This little epidemic affected 49 persons and caused 16 deaths. Typhus fever has almost disappeared, while some diseases have increased in relative frequency, in part at least because of medical progress. The children who would have died of smallpox in the eighteenth century now live to be affected with diphtheria or scarlet fever, and the increase in the number of deaths reported as due to cancer is partly due to the fact that a greater proportion of people live to the age most subject to this disease.

A large part of modern progress in medicine is due to improved methods of diagnosis and to the use of instruments of precision for recording the results of examinations. The use of the clinical thermometer has effected a revolution in medical practice. Our knowledge of diseases of the heart and lungs has been greatly expanded during the century by auscultation and percussion, and especially by the use of the stethoscope. The test tube and the microscope warn us of kidney troubles, which formerly would not have been suspected, and the mysterious Roentgen rays are called in to aid the surgeon in locating foreign bodies and in determining the precise nature of certain injuries of the bones. Bacteriological examination has become a necessary part of the examination in cases of suspected diphtheria, tuberculosis, or typhoid, and a minute drop of blood under the microscope may furnish data which will enable the skilled physician to predict the result in certain cases of anæmia, or to make a positive diagnosis as between malaria and other obscure forms of periodic fever.

The means at the command of the physician for the relief of pain now include, not only the general anæsthetics—chloroform, ether, and nitrous oxide—but also the hypodermic use of the concentrated alkaloids of opium, belladonna, and other narcotics, and the local use of cocaine; and restful sleep for the weary brain may be obtained by sulphonal, chloral, etc. Some agonizing forms of neuralgic pain are now promptly relieved by the section or excision of a portion of the affected nerve, or it may be forcibly stretched into a condition of innocuous desuetude. Relief to the sufferings of thousands of neurotic women, and of their families and friends, has been produced by the systematic scientific application of the rest cure of Dr. Weir Mitchell.

A hundred years ago the medical advertisement which was most prominent in New York and Philadelphia newspapers was one of a remedy for worms. Many symptoms of nervous and digestive troubles in children were in those days wrongly attributed to worms. Nevertheless there is good reason to believe that parasitic diseases derived from animals were much more prevalent in those days in this country than they are to-day. Our knowledge of the mode of origin and development of the tapeworm, the *Trichina spiralis*, the liver fluke, and the itch insect has been gained during the nineteenth century. Much the same may be said with regard to the peculiar worm known as *Anchylostum*, the cause of Egyptian chlorosis and of the St. Gothard tunnel disease, although prescriptions for this parasite are found in the Papyros Ebers, written before the time of Pharaoh.

The limits of this article permit of but a brief reference to the progress in preventive medicine during the century. The studies made in England of the results of the cholera epidemic of 1849, and the experience gained in the English army during the Crimean war, led to some of the most important advances in sanitary science, more especially to the demonstration of the importance of pure water supplies and of proper drainage and sewerage. During our Revolutionary war and the Napoleonic wars the losses to the armies from disease greatly exceeded those from wounds; and hospital fever—in other words, typhus—was dreaded by a general almost more than the opposing forces. During the wars of the last twenty-five years typhus and hospital gangrene have been unknown, but some extensive outbreaks of typhoid fever have occurred, showing that our knowledge of the causes and mode of transmission of this disease has not been practically applied to the extent which it should have been. This remark applies also to some of the most fatal diseases in civil life. In the

United States diphtheria and typhoid fever each causes from 20,000 to 30,000 deaths a year, while more than 100,000 deaths are annually due to consumption. Yet for each of these diseases we know the specific germ, the channels through which it is usually conveyed, and the means by which this conveyance can be to a great extent prevented. The ravages of these diseases are therefore largely due to the fact that the great mass of the people are still ignorant on these subjects. Antitoxin is not yet used for either prevention or treatment in diphtheria to anything like the extent which our knowledge of its powers demands.

Our better knowledge of the causes of certain infectious and contagious diseases and of the mode of their spread has been of great importance to the world from a purely commercial point of view, since it has led to the doing away with many unnecessary obstructions to traffic and travel, which were connected with the old systems of quarantine, while the security which has been gained from the modern method of cleansing and disinfection is decidedly greater than that secured by the old methods. A striking illustration of the effect of these improvements is seen in the manner in which the news of the recent outbreak of plague in Glasgow was received in England and throughout Europe. One hundred years ago the city would have been almost deserted, and terror would have reigned in all England. To-day it is well understood that the disease spreads by a bacillus which is not conveyed through the air. No one fears a repetition of the ghastly scenes of the Black Death in the fourteenth century. In like manner and for the same reasons Asiatic cholera has lost most of its terrors.

The benefits to the public of modern progress in medicine have been greatly enlarged by the establishment of many small hospitals and by the steady increase in the employment of specially trained nurses in private practice, even in rural districts. The result of a case of typhoid or of pneumonia often depends as much upon the nurse as upon the doctor, and affection can not take the place of skill in either. For the great mass of the people cases of severe illness or injury, or those requiring major surgical operations, can be treated more successfully in well-appointed hospitals than in private houses, and as this is becoming generally understood the old feeling against entering a hospital for treatment is rapidly disappearing. Improvement in hospital construction and management has kept pace with progress in medical knowledge, and in future such institutions seem destined to play an increasingly important part in municipal and village life.

All progress in civilization is attended with injury to some individuals. Trained nurses have deprived some unskilled labor of employment, hospitals have injured the business of some physicians, pure water supplies, good sewers, food inspection, vaccination—in short, all effective measures in public hygiene—interfere with the trade side of medical practice; but upon the whole the public at large benefits by all these things. In one sense they seem opposed to the general law of evolution in that they prolong the life of the unfit; but in a broader sense they work in accordance with this law by increasing the power of the strong to protect and care for the weak.

All told, the most important feature in the progress of medicine during the century has been the discovery of new methods of scientific investigation, more especially in the fields of bacteriology and pathology. These methods have been as yet only partially applied, and great results are to be hoped from their extension in the near future. They will not lead to the discovery of an elixir of life, and the increasing feebleness of old age will continue to be the certain result of living a long time, for the tissues and organs of each man have a definitely limited term of duration peculiar to himself; but many of the disorders which make life a burden in advancing years can now be palliated or so dealt with as to secure comparative comfort to the patient, so that "if by reason of strength" life can be prolonged beyond three-score years and ten, it no longer necessarily involves labor and sorrow.

MALARIA.[1]

By George M. Sternberg, M. D., LL. D.,
Surgeon-General United States Army.

In my address as president of the Biological Society, in 1896, the subject chosen was "The malarial parasite and other pathogenic protozoa." This address was published in March, 1897, in the Popular Science Monthly, and I must refer you to this illustrated paper for a detailed account of the morphological characters of the malarial parasite. It is my intention at the present time to speak of "malaria" in a more general way, and of the recent experimental evidence in support of Manson's suggestion, first made in 1894, that the mosquito serves as an intermediate host for the parasite. The discovery of this parasite may justly be considered one of the greatest achievements of scientific research during the nineteenth century. Twenty-five years ago the best-informed physicians entertained erroneous ideas with reference to the nature of malaria and the etiology of the malarial fevers. Observation had taught them that there was something in the air in the vicinity of marshes in tropical regions, and during the summer and autumn in semitropical and temperate regions, which gave rise to periodic fevers in those exposed in such localities, and the usual inference was that this something was of gaseous form—that it was a special kind of bad air generated in swampy localities under favorable meteorological conditions. It was recognized at the same time that there are other kinds of bad air, such as the offensive emanations from sewers and the products of respiration of man and animals, but the term malaria was reserved especially for the kind of bad air which was supposed to give rise to the so-called malarial fevers. In the light of our present knowledge it is evident that this term is a misnomer. There is no good reason for believing that the air of swamps is any more deleterious to those who breathe it than the air of the seacoast or that in the vicinity of inland lakes and ponds. Moreover, the stagnant pools which are covered with a "green scum," and from which bubbles of gas are given off, have lost all terrors for the well-informed

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[1] Annual address of the president of the Philosophical Society of Washington. Delivered under the auspices of the Washington Academy of Sciences, on December 8, 1900. Printed in Popular Science Monthly, February, 1901

man, except in so far as they serve as breeding places for mosquitoes of the genus *Anopheles*. The green scum is made up of harmless algæ, such as Spirogyra, Zygnema, Protococcus, Euglena, etc.; and the gas which is given off from the mud at the bottom of such stagnant pools is for the most part a well-known and comparatively harmless compound of hydrogen and carbon—methane or "marsh gas." In short, we now know that the air in the vicinity of marshes is not deleterious because of any special kind of bad air present in such localities, but because it contains mosquitoes infected with a parasite known to be the specific cause of the so-called malarial fevers. This parasite was discovered in the blood of patients suffering from intermittent fevers by Laveran, a surgeon in the French army, whose investigations were conducted in Algiers. This famous discovery was made toward the end of the year 1880, but it was several years later before the profession generally began to attach much importance to the alleged discovery. It was first confirmed by Richard in 1882; then by the Italian investigators, Marchiafava, Celli, Golgi, and Bignami; by Councilman, Osler, and Thayer, in this country, and by many other competent observers in various parts of the world. The Italian investigators named not only confirmed the presence of the parasite discovered by Laveran in the blood of those suffering from malarial fevers, but they demonstrated its etiological rôle by inoculation experiments and added greatly to our knowledge of its life history (1883–1898). The fact that the life history of the parasite includes a period of existence in the body of the mosquito as an intermediate host has recently been demonstrated by the English army surgeons Manson and Ross, and confirmed by numerous observers, including the famous German bacteriologist, Koch.

The discoveries referred to, as is usual, have had to withstand the criticism of conservative physicians, who, having adopted the prevailing theories with reference to the etiology of periodic fevers, were naturally skeptical as to the reliability of the observations made by Laveran and those who claimed to have confirmed his discovery. The first contention was that the bodies described as present in the blood were not parasites, but deformed blood corpuscles. This objection was soon set at rest by the demonstration, repeatedly made, that the intra-corpuscular forms underwent distinct amœboid movements. No one witnessing these movements could doubt that he was observing a living microorganism. The same was true of the extra-corpuscular flagellate bodies, which may be seen to undergo very active movements, as a result of which the red blood corpuscles are violently displaced and the flagellate body itself dashes about in the field of view.

The first confirmation in this country of Laveran's discovery of amœboid parasites in the blood of malarial-fever patients was made by myself in the pathological laboratory of the Johns Hopkins University in March, 1886. In May, 1885, I had visited Rome as a delegate to the International Sanitary Conference, convened in that city under the auspices of the Italian Government, and while there I visited the Santo Spirito Hospital for the purpose of witnessing a demonstration, by Drs. Marchiafava and Celli, of that city, of the presence of the *plasmodium malariæ* in the blood of persons suffering from intermittent fever. Blood was drawn from the finger during the febrile attack and from individuals to whom quinine had not been administered. The demonstration was entirely satisfactory, and no doubt was left in my mind that I saw living parasitic micro-organisms in the interior of red blood corpuscles obtained from the circulation of malarial-fever patients. The motions were quite slow, and were manifested by a gradual change of outline rather than by visible movement. After a period of amœboid activity of greater or less duration, the body again assumed an oval or spherical form and remained quiescent for a time. While in this form it was easily recognized, as the spherical shape caused the light passing through it to be refracted, and gave the impression of a body having a dark contour and a central vacuole, but when it was flattened out and undergoing amœboid changes in form it was necessary to focus very carefully and to have a good illumination in order to see it. The objective used was a Zeiss's one-twelfth inch homogeneous oil immersion.

But, very properly, skepticism with reference to the casual relation of these bodies to the disease with which they are associated was not removed by the demonstration that they are in fact blood parasites, that they are present in considerable numbers during the febrile paroxysms, and that they disappear during the interval between these paroxysms. These facts, however, give strong support to the inference that they are indeed the cause of the disease. This inference is further supported by the evident destruction of red blood corpuscles by the parasite, as shown by the presence of grains of black pigment in the amœba-like micro-organisms observed in these corpuscles and the accumulation of this insoluble blood pigment in the liver and spleen of those who have suffered repeated attacks of intermittent fever. The enormous loss of red blood corpuscles as a result of such attacks is shown by the anæmic condition of the patient and also by actual enumeration. According to Kelsch, a patient of vigorous constitution in the first four days of a quotidian intermittent fever, or a remittent of first invasion, may suffer a loss of 2,000,000 of red blood corpuscles per cubic millimeter of blood, and in certain cases a loss of 1,000,000 has been verified at the end of twenty-four hours. In cases of intermittent fever having a duration of twenty to thirty days the number of red blood cells may be reduced from the normal, which is about 5,000,000 per cubic millimeter, to 1,000,000, or even less. In view of this destruction of the red blood cells and the demonstrated fact that a certain number at least are destroyed during the febrile paroxysms by a blood parasite which invades the cells and grows at the expense of the continued hæmoglobin, it may be thought that the etiological rôle of the parasite should be conceded. But scientific conservatism demands more than this, and the final proof has been afforded by the experiments of Gerhardt and of Marchiafava and Celli—since confirmed by many others. This proof consists in the experimental inoculation of healthy individuals with blood containing the parasite and the development of a typical attack of periodic fever as a result of such inoculation. Marchiafava and Bignami, in their elaborate article upon "Malaria," published in the "Twentieth Century Practice of Medicine," say:

> The transmission of the disease occurs equally whether the blood is taken during the apyretic period or during a febrile paroxysm, whether it contains young parasites or those in process of development, or whether it contains sporulation forms. Only the crescent forms, when injected alone, do not transmit the infection, as has been demonstrated by Bastianelli, Bignami, and Thayer, and as can be readily understood when we remember the biological significance of these forms.
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> In order that the disease be reproduced in the inoculated subject, it is not necessary to inject the malarial blood into a vein of the recipient, as has been done in most of the experiments; a subcutaneous injection is all-sufficient. Nor is it necessary to inject several cubic centimeters as was done especially in the earlier experiments; a fraction of a cubic centimeter will suffice and even less than one drop, as Bignami has shown.

After the inoculation of a healthy individual with blood containing the parasite a period varying from four to twenty-one days elapses before the occurrence of a febrile paroxysm. This is the so-called period of incubation, during which, no doubt, the parasite is undergoing multiplication in the blood of the inoculated individual. The duration of this period depends to some extent upon the quantity of blood used for the inoculation and its richness in parasites. It also depends upon the particular variety of the parasite present, for it has been ascertained that there are at least three distinct varieties of the malarial parasite—one which produces the quartan type of fever, in which there is a paroxysm every third day and in which, in experimental inoculations made, the period of incubation has varied from eleven to eighteen days; in the tertian type, or second day fever, the period of incubation noted has been from nine to twelve days; and in the æstivo-autumnal type the duration has usually not exceeded five days. The parasite associated with each of these types of fever may be recognized by an expert, and there is no longer any doubt that the difference in type is due to the fact that different varieties or "species" of the malarial parasite exist, each having a different period of development. Blood drawn during a febrile paroxysm shows the parasite in its different stages of intra-corpuscular development. The final result of this development is a segmenting body, having pigment granules at its center, which occupies the greater part of the interior of the red corpuscle. The number of segments into which this body divides differs in the different types of fever, and there are other points of difference by which the several varieties may be distinguished one from the other, but which it is not necessary to mention at the present time. The important point is that the result of the segmentation of the adult parasites contained in the red corpuscles is the formation of a large number of spore-like bodies, which are set free by the disintegration of the remains of the blood corpuscles and which constitute a new brood of reproductive elements, which in their turn invade healthy blood corpuscles and effect their destruction. This cycle of development, without doubt, accounts for the periodicity of the characteristic febrile paroxysms; and, as stated, the different varieties complete their cycle of development in different periods of time, thus accounting for the recurrence of the paroxysms at intervals of forty-eight hours in one type of fever and of three days in another type. When a daily paroxysm occurs, this is believed to be due to the alternate development of two groups of parasites of the tertian variety, as it has not been possible to distinguish the parasite found in the blood of persons suffering from a quotidian form of intermittent fever from that of the tertian form. Very often, also, the daily paroxysm occurs on succeeding days at a different hour, while the paroxysm every alternate day is at the same hour, a fact which sustains the view that we have to deal, in such cases, with two broods of the tertian parasite which mature on alternate days. In other cases there may be two distinct paroxysms on the same day and none on the following day, indicating the presence of two broods of tertian parasites maturing at different hours every second day.

Manson, in his work on tropical diseases, recently published, accounts for the febrile paroxysm as follows:

> In all malarial attacks this periodicity tends to become, and in most attacks actually is, quotidian, tertian, or quartan in type. If we study the parasites associated with these various types we find that they, too, as has been fully described already, have a corresponding periodicity. We have also seen that the commencement of the fever in each case corresponds with the breaking up of the sporulating form of the parasite concerned. This last is an important point; for, doubtless, when this breaking up takes place, besides the pigment set free, other residual matters—not so striking optically, it is true, as the pigment, but none the less real—probably are liberated; a hæmoglobin solvent, for example, as I have suggested. Whether it be this hæmoglobin solvent, or whether it be some other substance, which is the pyrogenetic agent, I believe that some toxin, hitherto inclosed in the body of the parasite, or in the infected corpuscle, escapes into the blood at the moment of sporulation.
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> The periodicity of the clinical phenomena is accounted for by the periodicity of the parasite. How are we to account for the periodicity of the parasite? It is true that it has a life of twenty-four hours, or of a multiple of twenty-four hours; but why should the individual parasites of the countless swarm all conspire to mature at or about the same time? That they do so—not perhaps exactly at the same moment, but within a very short time of each other—is a fact, and it is one which can be easily demonstrated. If we wish to see the sporulating forms of the plasmodium in a pure intermittent, it is practically useless to look for them in the blood during the

later stages of fever, or during the interval, or during any time but just before, during, or soon after rigor. If we wish to see the early and unpigmented forms, we must look for them during the later stage of rigor or the earlier part of the stage of pyrexia. And so with the other stages of the parasite; each has its appropriate relationship to the fever cycle.

There are numerous cases of malarial fever in which there is no distinct intermission and in which the course of the fever is either continued or remittent in character. Fevers of this type usually occur in the late summer or in the autumn (æstivo-autumnal) and are believed to be due to infection by two distinct varieties of the parasite; one, the tertian æstivo-autumnal, causes a fever characterized by a marked rise in the temperature every second day; the other, a fever in which there is a daily elevation of temperature. There are certain peculiarities relating to the intra-corpuscular development of these parasites which enable us to differentiate them from the tertian and quartan parasites of intermittent fever, but a more striking difference to be observed in their life cycle of development in the blood of man is the presence of peculiar crescentic-shaped bodies, which play an important part in their further development in the body of an intermediate host—the mosquito. Associated with these "crescents" fusiform and ovoid bodies are often seen which are no doubt similar in their origin and function. The crescents are a little longer than the diameter of a red blood corpuscle and are about three times as long as broad. They contain in the central portion grains of pigment (melanin) derived from the hæmoglobin of the infected corpuscle, which has been changed into a crescentic body as a result of the development of the malarial parasite in its interior. When a fresh preparation of malarial blood containing these crescents is observed under the microscope, while a majority of them retain the crescentic form, others may be seen, after an interval of ten minutes or more, to change in form, first becoming oval and then round; then, in the interior of these round bodies an active movement of the pigment granules occurs; this is followed by the thrusting forth from the periphery of several filaments—usually four—which have flagella-like movements. These, as a rule, become detached and continue to move rapidly among the blood corpuscles. With reference to the function of these motile filaments, Marchiafava says:

> In these later days there is increasing belief in the theory, which we uphold, that the crescents and the flagellata are sexual forms of the malarial parasite, and that a reproductive act (in which the flagellum represents the male element and an adult crescent the female cell) gives rise to the new being which begins its existence in the tissues of the mosquito.

The crescentic bodies may be found in the blood of man long after all febrile symptoms have disappeared, and it is generally recognized that they are not directly concerned in the production of the phenomena which constitute a malarial attack and that the administration of quinine has no influence in causing them to disappear from the blood.

On the other hand, the febrile phenomena are directly associated with the appearance of the amœboid form of the parasite in the interior of the red blood corpuscles, and the administration of suitable doses of quinine has a marked effect in causing these amœba-like micro-organisms to disappear from the blood.

These crescentic bodies are not found in the benign tertian and quartan intermittent fevers, but are characteristic of the malignant forms of malarial infection, including the so-called æstivo-autumnal fever. In these forms of fever they are not seen at the outset of the attack, and they have no direct influence upon the course of the fever. A week usually elapses between the first appearance of the amœboid form of the parasite and that of these crescentic bodies. They are often found in the blood some time after all symptoms of fever have disappeared, and are associated with the malarial cachexia which follows an attack of æstivo-autumnal fever. When blood containing these crescents is ingested by a mosquito of the genus *Anopheles*, the following very remarkable transformations occur: Some of the crescents are transformed into hyaline flagellate bodies having active movements; others are changed into granular spheres. The flagella break away from the hyaline bodies and, approaching the granular spheres, appear to seek energetically to enter these bodies. A minute papilla is given off from the surface of the sphere, seeming to be projected to meet the attacking flagellum. At this point, one of the flagella succeeds in entering the sphere, causing an active movement of its contents for a brief time, after which the flagellum disappears from view and the contents become quiescent. This is no doubt an act of impregnation. After a time the impregnated granular sphere alters its shape, becoming oval, and later vermicular in form. The pigment granules are now seen at the posterior part of this body, which, after the changes mentioned, exhibits active movements. It is believed that this motile vermicular body penetrates the wall of the mosquito's stomach. Here it grows rapidly and, after a few days, may be seen projecting from the surface as a spherical mass. In the meantime the contents are transformed into spindle-shaped bodies (sporozoites) which are subsequently set free by the rupture of the capsule of the mother cell. According to Manson, these spindle-shaped bodies pass from the body cavity of the mosquito, probably by way of the blood, to the 3-lobed veneno-salivary glands lying on each side of the fore part of the thorax of the insect. "These glands communicate with the base of the mosquito's proboscis by means of a long duct, along the radicles of which the clear, plump cells of the gland are arranged. The sporozoites can be readily recognized in many, though not in all, of the cells, especially in those of the middle lobe, and also free in the ducts. So numerous are they in some of the cells that the appearance they present is suggestive of a bacillus-laden lepra-cell."

The hypothesis that malarial infection results from the bites of mosquitoes was advanced and ably supported by Dr. A. F. A. King, of Washington, D. C., in a paper read before the Philosophical Society on February 10, 1883, and published in the Popular Science Monthly in September of the same year. In 1894 Manson supported the same hypothesis in a paper published in the British Medical Journal (December 8), and the following year (1895) Ross made the important discovery that when blood containing the crescentic bodies was ingested by the mosquito these crescents rapidly underwent changes similar to those heretofore described, resulting in the formation of motile filaments, which become detached from the parent body and continue to exhibit active movements. In 1897 Ross ascertained further that when blood containing crescents was fed to a particular species of mosquito, living pigmented parasites could be found in the stomach walls of the insect. Continuing his researches with a parasite of the same class which is found in birds, and in which the mosquito also serves as an intermediate host, Ross found that this parasite enters the stomach wall of the insect, and, as a result of its development in that locality, forms reproductive bodies (sporozoites), which subsequently find their way to the veneno-salivary glands of the insect which is now capable of infecting other birds of the same species as that from which the blood was obtained in the first instance. Ross further showed that the mosquito which served as an intermediate host for this parasite could not transmit the malarial parasite of man or another similar parasite of birds (halteridium). These discoveries of Ross have been confirmed by Grassi, Koch, and others, and it has been shown that the mosquitoes which serve as intermediate hosts for the malarial parasites of man belong to the genus *Anopheles*, and especially to the species known as *Anopheles claviger*.

The question whether mosquitoes infected with the malarial parasite invariably become infected as a result of the ingestion of human blood containing this parasite has not been settled in a definite manner, but certain facts indicate that this is not the case. Thus there are localities noted for being extremely dangerous on account of the malarial fevers contracted by those who visit them, which on this very account are rarely visited by man. Yet there must be a great abundance of infected mosquitoes in these localities, and especially in low, swampy regions in the Tropics. If man and the mosquitoes are alone concerned in the propagation of this parasite, how shall we account for the abundance of infected mosquitoes in uninhabited marshes? It appears probable that some other vertebrate animal serves in place of man to maintain the life cycle of the parasite, or that it may be propagated through successive generations of mosquitoes.

It is well known that persons engaged in digging canals, railroad cuts, etc., in malarious regions are especially liable to be attacked with one or the other of the forms of malarial fever. This may be due to the fact that the digging operations result in the formation of little pools suitable for the development of the eggs of *Anopheles;* but another explanation has been offered. Ross and others have found in infected mosquitoes certain bodies, described by Ross as "black spores," which resist decomposition and which may be resting spores capable of retaining their vitality for a long time. The suggestion is that these "black spores" or other encysted reproductive bodies may have been deposited in the soil by mosquitoes long since defunct, "and that in moving the soil these dormant parasites are set at liberty, and so in air, in water, or otherwise gain access to the workmen engaged" (Manson). This hypothesis is not supported by recent observations, which indicate that infection in man occurs only as a result of inoculation through the bite of an infected mosquito. The question is whether malarial fevers can be contracted in marshy localities independently of the mosquito, which has been demonstrated to be an intermediate host of the malarial parasite? Is this parasite present in the air or water in such localities, as well as in the bodies of infected mosquitoes? Its presence has never been demonstrated by the microscope; but this fact has little value in view of the great variety of microorganisms present in marsh water or suspended in the air everywhere near the surface of the ground, and the difficulty of recognizing the elementary reproductive bodies by which the various species are maintained through successive generations. It would appear that a crucial experiment for the determination of this question would be to expose healthy individuals in a malarious region and to exclude the mosquito by some appropriate means. This experiment has been made during the past summer, and the result up to the present time has been reported by Manson in the London Lancet of September 29. Five healthy individuals have lived in a hut on the Roman Campagna since early in the month of July. They have been protected against mosquito bites by mosquito-netting screens in the doors and windows and by mosquito bars over the beds. They go about freely during the daytime, but remain in their protected hut from sunset to sunrise. At the time Manson made his report all these individuals remained in perfect health. It has long been known that laborers could come from the villages in the mountainous regions near the Roman Campagna and work during the day, returning to their homes at night, without great danger of contracting the fever, while those who remained on the Campagna at night ran great risk of falling sick with fever, as a result of "exposure to the night air." What has already been said makes it appear extremely probable that the "night air," per se, is no more dangerous than the day air, but that the real danger consists in the presence of infected mosquitoes of a species which seeks its food at night. As pointed out by King, in his paper already referred to, it has repeatedly been claimed by travelers in malarious regions that sleeping under a mosquito bar is an effectual method of prophylaxis against intermittent fevers.

That malarial fevers may be transmitted by mosquitoes of the genus *Anopheles* was first demonstrated by the Italian physician Bignami, whose experiments were made in the Santo Spirito Hospital in Rome. The subjects of the experiment, with their full consent, were placed in a suitable room and exposed to the bites of mosquitoes brought from Maccarese, "a marshy place with an evil but deserved reputation for the intensity of its fevers." It has been objected to these experiments that they were made in Rome, at a season of the year when malarial fevers prevail to a greater or less extent in that city, but Marchiafava and Bignami say:

> It is well known to all physicians here that, although there are some centers of malaria in certain portions of the suburbs, the city proper is entirely free from malaria, as long experience has demonstrated, and at no season of the year does one acquire the disease in Rome.

In view of the objection made, a crucial experiment has recently been made in the city of London. The result is reported by Manson, as follows:

> Mosquitoes infected with the parasite of benign tertian malarial fever were sent from Rome to England, and were allowed to feed upon the blood of a perfectly healthy individual (Dr. Manson's son, who had never had malarial disease). Forty mosquitoes in all were allowed to bite him between August 29 and September 12. On September 14 he had a rise of temperature, with headache and slight chilliness, but no organisms were found in his blood. A febrile paroxysm occurred daily thereafter, but the parasites did not appear in the blood until September 17, when large numbers of typical tertian parasites were found. They soon disappeared under the influence of quinine.[1]

We have still to consider the question of the transmission of malarial fevers by the ingestion of water from malarious localities. Numerous medical authors have recorded facts which they deemed convincing as showing that malarial fevers may be contracted in this way. I have long been of the opinion that while the observed facts may, for the most part, be authentic, the inference is based upon a mistake in diagnosis; that, in truth, the fevers which can justly be ascribed to the ingestion of a contaminated water supply are not true malarial fevers—i. e., they are not due to the presence of the malarial parasite in the blood. This view was sustained by me in my work on "Malaria and Malarial Diseases," published in 1883. The fevers supposed to have been contracted in this way are, as a rule, continued or remittent in character, and they are known under a variety of names. Thus we have "Roman fever," "Naples fever," "remittent fever," "mountain fever," "typho-malarial fever," etc. The leading physicians and pathologists, in regions where these fevers prevail, are now convinced that they are not malarial fevers, but are simply more or less typical varieties of typhoid fever—a disease due to a specific bacillus and which is commonly contracted as a result of the ingestion of contaminated water or food.

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[1] Quoted from an editorial in the New York Medical Journal of October 20, 1900.

The error in diagnosis, upon which the inference has been based that malarial fevers may be contracted through drinking water, has been widespread, in this country, in Europe and the British possessions in India. It vitiated our medical statistics of the civil war and of the recent war with Spain. In my work already referred to I say:

> Probably one of the most common mistakes in diagnosis, made in all parts of the world where malarial and enteric fevers are endemic, is that of calling an attack of fever belonging to the last-mentioned category malarial remittent. This arises from the difficulties attending a differential diagnosis at the outset, and from the fact that having once made a diagnosis of malarial fever the physician, even if convinced later that a mistake has been made, does not always feel willing to confess it. The case, therefore, appears in the mortality returns if it prove fatal, or in the statistical reports of disease if made by an army or navy surgeon, as at first diagnosed.

I have already mentioned the fact that Marchiafava denies that malarial fevers prevail in the city of Rome, yet everyone knows how frequently travelers contract the so-called "Roman fever" as a result of a temporary residence in that city. In our own cities numerous cases of so-called "remittent" or "typho-malarial" fevers are reported in localities where typical malarial fevers (intermittents) are unknown, and at seasons of the year when these fevers do not prevail even in the marshy regions where they are of annual occurrence, during the mosquito season. Malarial fevers may, of course, occur in cities as a result of exposure elsewhere to the bites of infected mosquitoes of the genus *Anopheles*, either as primary attacks or as a relapse, or in urban localities in the vicinity of marshy places or pools of water suitable as breeding places for *Anopheles*. But when a previously healthy individual, living in a well-paved city, in a locality remote from all swampy places is taken sick with a "remittent fever," and especially when the attack occurs during the winter months, it is pretty safe to say that he is not suffering from malarial infection, and the chances are greatly in favor of the view that he has typhoid fever. It must be remembered that a remittent or intermittent course is not peculiar to malarial fevers. Typhoid commonly presents a more or less remittent character, especially at the outset of an attack; the hectic fever of tuberculosis is intermittent in character. The formation of an abscess, an attack of tonsilitis, etc., are usually attended by chills and fever, which may recur at more or less regular intervals. Indeed, in certain cases of pyæmia the febrile phenomena are so similar to those of a malarial attack that a mistake in diagnosis is no unusual occurrence. Finally, I may say that it is the fashion with many persons and with some physicians to ascribe a variety of symptoms, due to various causes, to "malaria" and to prescribe quinine as a general panacea. Thus a gentleman who has been at the club until 1 or 2 o'clock at night and has smoked half a dozen cigars—not to mention beer and cheese sandwiches as possible factors—reports to his doctor the next morning with a dull headache, a furred tongue, and a loss of appetite which he is unable to account for except upon the supposition that he has "malaria." Again the symptoms arising from indigestion, from crowd poisoning, from sewer-gas poisoning, from ptomaine poisoning (auto-infection), etc., are often ascribed to "malaria," and quinine is prescribed, frequently with more or less benefit, for the usefulness of this drug is not limited to its specific action in the destruction of the malarial parasite.

As stated at the outset, it is evident, in the present state of our knowledge, that the term "malaria" is a misnomer, either as applied to the cause of the periodic fevers or as used to designate this class of fevers. It would be more logical to use the name plasmodium fever and to speak of a plasmodium intermittent or remittent, rather than of a malarial intermittent. But it will, no doubt, be difficult to displace a term which has been so long in use, which up to the present time has had the sanction of the medical profession, and which expresses the popular idea as to the origin of that class of fevers which we now know to be due to a blood parasite, introduced through the agency of mosquitoes of the genus *Anopheles*.

TRANSMISSION OF YELLOW FEVER BY MOSQUITOES.

By George M. Sternberg, M. D., LL. D.,
Surgeon-General United States Army.

The discoveries which have been made during the past twenty-five years with reference to the etiology of infectious diseases constitute the greatest achievement of scientific medicine and afford a substantial basis for the application of intelligent measures of prophylaxis. We now know the specific cause (germ) of typhoid fever, of pulmonary consumption, of cholera, of diphtheria, of erysipelas, of croupous pneumonia, of the malarial fevers, and of various other infectious diseases of man and of the domestic animals; but up to the present time all efforts to discover the germ of yellow fever have been without success. The present writer, as a member of the Havana Yellow Fever Commission, in 1879, made the first systematic attempt to solve the unsettled questions relating to yellow-fever etiology by modern methods of research. Naturally the first and most important question to engage my attention was that relating to the specific infectious agent, or germ, which there was every reason to believe must be found in the bodies of infected individuals. Was this germ present in the blood, as in the case of relapsing fever; or was it to be found in the organs and tissues which upon post-mortem examination give evidence of pathological changes, as in typhoid fever, pneumonia, and diphtheria; or was it to be found in the alimentary canal, as in cholera and dysentery? The clinical history of the disease indicated a general blood infection. As my equipment included the best microscopical apparatus made, I had strong hopes that in properly stained preparations of blood taken from the circulation of yellow-fever patients my Zeiss 1/18 oil immersion objective would reveal to me the germ I was in search of; but I was doomed to disappointment. Repeated examinations of blood from patients in every stage of the disease failed to demonstrate the presence of micro-organisms of any kind. My subsequent investigations in Havana, Vera Cruz, and Rio de Janeiro, made in 1887, 1888, and 1889, were equally unsuccessful. And numerous competent microscopists of various nations have since searched in vain for this elusive germ. Another method of attacking this problem consists in introducing blood from yellow-fever patients or recent cadavers into various culture media for the purpose of cultivating any germ that might be present. Extended researches of this kind also gave a negative result, which in my final report I stated as follows:

> The specific cause of yellow fever has not yet been demonstrated.
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> It is demonstrated that micro-organisms capable of development in the culture-media usually employed by bacteriologists, are only found in the blood and tissues of yellow-fever cadavers in exceptional cases, when cultures are made very soon after death.

Since this report was made various investigators have attacked the question of yellow-fever etiology, and one of them has made very positive claims to the discovery of the specific germ. I refer to the Italian bacteriologist, Sanarelli. His researches were made in Brazil, and, singularly enough, he found in the blood of the first case examined by him a bacillus. It was present in large numbers, but this case proved to be unique, for neither Sanarelli nor anyone else has since found it in such abundance. It has been found in small numbers in the blood and tissues of yellow-fever cadavers in a certain number of the cases examined. But carefully conducted researches by competent bacteriologists have failed to demonstrate its presence in a considerable proportion of the cases, and the recent researches of Reed, Carroll, and Agramonte, to which I shall shortly refer, demonstrate conclusively that the bacillus of Sanarelli has nothing to do with the etiology of yellow fever.

So far as I am aware, Dr. Carlos Finlay, of Havana, Cuba, was the first to suggest the transmission of yellow fever by mosquitoes. In a communication made to the Academy of Sciences of Havana, in October, 1881, he gave an account of his first attempts to demonstrate the truth of his theory. In a paper contributed to the Edinburg Medical Journal, in 1894, Doctor Finlay gives a summary of his experimental inoculations up to that date, as follows:

> A summary account of the experiments performed by myself (and some also by my friend Doctor Delgado) during the last twelve years will enable the reader to judge for himself. The experiment has consisted in first applying a captive mosquito to a yellow-fever patient, allowing it to introduce its lance and to fill itself with blood; next, after the lapse of two or more days, applying the same mosquito to the skin of a person who is considered susceptible to yellow fever, and, finally, observing the effects, not only during the first few weeks, but during periods of several years, so as to appreciate the amount of immunity that should follow.
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> Between the 30th of June, 1881, and the 2d of December, 1893, 88 persons have been so inoculated. All were white adults, uniting the conditions which justify the assumption that they were susceptible to yellow fever. Only 3 were women. The chronological distribution of the inoculations was as follows: Seven in 1881, 10 in 1883, 9 in 1885, 3 in 1886, 12 in 1887, 9 in 1888, 7 in 1889, 10 in 1890, 8 in 1891, 3 in 1892, and 10 in 1893. The following table will show the length of time during which the "inoculated" resided in Havana (as also some ten or twelve who resided most of the time in Cienfuegos). During this time the inoculated were under observation, so far, at least, as to obtain information about any attack of yellow fever that

> was suffered by them (with the exception of only one case, that of a youth who was lost sight of after the inoculation).
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> | | Cases. | | Cases. |
> |---|---|---|---|
> | Result unknown in | 1 | Five years in | 2 |
> | Less than one year in | 11 | Six years in | 8 |
> | One year in | 3 | Seven to ten years in | 9 |
> | Two years in | 12 | | |
> | Three years in | 14 | Total | 87 |
> | Four years in | 28 | | |
>
> The yellow-fever patients upon whom the mosquitoes were contaminated were, almost in every instance, well-marked cases of the albuminuric or melano-albuminuric forms, in the second, third, fourth, fifth, or sixth day of the disease. In some of the susceptible subjects the inoculation was repeated when the source of the contamination appeared uncertain.
>
> Among the 87 who have been under observation, the following results have been recorded.
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> 1. Within a term of days, varying between five and twenty-five after the inoculation, 1 presented a mild albuminuric attack, and 13 only "acclimation fevers."

While Finlay's theory appeared to be plausible and to explain many of the facts relating to the etiology of yellow fever, his experimental inoculations not only failed to give it substantial support, but the negative results, as reported by himself, seemed to be opposed to the view that yellow fever is transmitted by the mosquito. It is true that he reports one case which "presented a mild albuminuric attack," which we may accept as an attack of yellow fever. But in view of the fact that this case occurred in the city of Havana, where yellow fever is endemic, and of the 86 negative results from similar inoculations, the inference seemed justified that in this case the disease was contracted in some other way than as a result of the so-called "mosquito inoculation." The 13 cases in which "only acclimation fevers" occurred "within a term of days varying between five and twenty-five after the inoculation" appeared to me to have no value as giving support to Finlay's theory; first, because these "acclimation fevers" could not be identified as mild cases of yellow fever; second, because the ordinary period of incubation in yellow fever is less than five days, and third, because these individuals, having recently arrived in Havana, were liable to attacks of yellow fever or of "acclimation fever" as a result of their residence in that city and quite independently of Doctor Finlay's mosquito inoculations. For these reasons Doctor Finlay's experiments failed to convince the medical profession generally of the truth of his theory relating to the transmission of yellow fever, and this important question remained in doubt and a subject of controversy. One party regarded the disease as personally contagious and supposed it to be communicated directly from the sick to the well, as in the case of other contagious diseases, such as smallpox, scarlet fever, etc. Opposed to this theory was the fact that in innumerable instances nonimmune persons had been known to care for yellow-fever patients as nurses or physicians without contracting the disease;

also the fact that the epidemic extension of the disease depends upon external conditions relating to temperature, altitude, rainfall, etc. It was a well-established fact that the disease is arrested by cold weather and does not prevail in northern latitudes or at considerable elevations. But diseases which are directly transmitted from man to man by personal contact have no such limitations. The alternate theory took account of the above-mentioned facts and assumed that the disease was indirectly transmitted from the sick to the well, as is the case in typhoid fever and cholera, and that the germ was capable of development external to the human body when conditions were favorable. These conditions were believed to be a certain elevation of temperature, the presence of moisture, and suitable organic pabulum (filth). The two first-mentioned conditions were known to be essential; the third was a subject of controversy.

Yellow-fever epidemics do not occur in the winter months in the temperate zone, and they do not occur in arid regions. As epidemics have frequently prevailed in seacoast cities known to be in an insanitary condition, it has been generally assumed that the presence of decomposing organic material is favorable for the development of an epidemic, and that, like typhoid fever and cholera, yellow fever is a "filth disease." Opposed to this view, however, was the fact that epidemics have frequently occurred in localities (e. g., at military posts) where no local insanitary conditions were to be found. Moreover, there are marked differences in regard to the transmission of the recognized filth diseases—typhoid fever and cholera—and yellow fever. The first-mentioned diseases are largely propagated by means of a contaminated-water supply, whereas there is no evidence that yellow fever is ever communicated in this way.

Typhoid fever and cholera prevail in all parts of the world and may prevail at any season of the year, although cholera as a rule is a disease of the summer months. On the other hand, yellow fever has a very restricted area of prevalence, and is essentially a disease of seaboard cities and of warm climates. Evidently neither of the theories referred to accounts for all of the observed facts with reference to the endemic prevalence and epidemic extension of the disease under consideration.

Having for years given much thought to this subject, I became some time since impressed with the view that probably in yellow fever, as in the malarial fevers, there is an intermediate host. I therefore suggested to Doctor Reed, president of a board[1] appointed upon my recommendation for the study of this disease in the island of Cuba, that he should give special attention to the possibility of transmission by some insect, although the experiments of Finlay seemed to show

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[1] The members of the board were: Maj. Walter Reed, surgeon, U. S. A.; Dr. James Carroll, contract surgeon, U. S. A.; Dr. A. Agramonte, contract surgeon, U. S. A., and Dr. Jesse Lazear, contract surgeon, U. S. A.

that this insect was not a mosquito of the genus *Culex*, such as he had used in his inoculation experiments. I also urged that efforts should be made to ascertain definitely whether the disease can be communicated from man to man by blood inoculations. Evidently, if this is the case the blood must contain the living infectious agent upon which the propagation of the disease depends, notwithstanding the fact that all attempts to demonstrate the presence of such a germ in the blood by means of the microscope and culture methods had proved unavailing. I had previously demonstrated by repeated experiments that inoculations of yellow-fever blood into lower animals—dogs, rabbits, guinea pigs—give a negative result; but this negative result might well be because these animals were not susceptible to the disease and could not be accepted as showing that the germ of yellow fever was not present in the blood. A single inoculation experiment on man had been made in my presence in the city of Vera Cruz in 1887 by Dr. Daniel Ruiz, who was in charge of the civil hospital in that city. But this experiment was inconclusive, for the reason that the patient from whom the blood was obtained was in the eighth day of the disease, and it was quite possible that the specific germ might have been present at an earlier period and that after a certain number of days the natural resources of the body are sufficient to effect its destruction, or in some way to cause its disappearance from the circulation.

This was the status of the question of yellow-fever etiology when Doctor Reed and his associates commenced their investigations in Cuba during the summer of 1900. In a "Preliminary note" read at the meeting of the American Public Health Association, October 22, 1900, the board gave a report of three cases of yellow fever which they believed to be the direct result of mosquito inoculations. Two of these were members of the board, viz: Dr. Jesse W. Lazear and Dr. James Carroll, who voluntarily submitted themselves to the experiment. Doctor Carroll suffered a severe attack of the disease and recovered, but Doctor Lazear fell a victim to his enthusiasm in the cause of science and humanity. His death occurred on September 25, after an illness of six days' duration. About the same time nine other individuals who volunteered for the experiment were bitten by infected mosquitoes—i. e., by mosquitoes which had previously been allowed to fill themselves with blood from yellow-fever cases—and in these cases the result was negative. In considering the experimental evidence thus far obtained the attention of the members of the board was attracted by the fact that in the nine inoculations with a negative result "the time elapsing between the biting of the mosquito and the inoculation of the healthy subject varied in seven cases from two to eight days and in the remaining two from ten to thirteen days, whereas in two of the three successful cases the mosquito had been kept for twelve days or longer. In the third case—that of Doctor Lazear—the facts are stated in the report of the board as follows:

> *Case 3.*—Dr. Jesse W. Lazear, acting assistant surgeon, United States Army, a member of this board, was bitten on August 16, 1900 (case 3, Table III), by a mosquito (*Culex fasciatus*), which ten days previously had been contaminated by biting a very mild case of yellow fever (fifth day). No appreciable disturbance of health followed this inoculation.
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> On September 13, 1900 (forenoon), Doctor Lazear, while on a visit to Las Animas Hospital, and while collecting blood from yellow-fever patients for study, was bitten by a Culex mosquito (variety undetermined). As Doctor Lazear had been previously bitten by a contaminated insect without after effects, he deliberately allowed this particular mosquito, which had settled on the back of his hand, to remain until it had satisfied its hunger.
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> On the evening of September 18, five days after the bite, Doctor Lazear complained of feeling "out of sorts," and had a chill at 8 p. m.
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> On September 19, 12 o'clock noon, his temperature was 102.4°; pulse, 112. His eyes were injected and his face suffused. At 3 p. m. temperature was 103.4°; pulse, 104; 6 p. m. temperature, 103.8°, and pulse, 106. Albumin appeared in the urine. Jaundice appeared on the third day. The subsequent history of this case was one of progressive and fatal yellow fever, the death of our much-lamented colleague having occurred on the evening of September 25, 1900.

Evidently in this case the evidence is not satisfactory as to the fatal attack being a result of the bite by a mosquito "while on a visit to Las Animas Hospital," although Doctor Lazear himself was thoroughly convinced that this was the direct cause of his attack.

The inference drawn by Doctor Reed and his associates from the experiments thus far made was that yellow fever may be transmitted by mosquitoes of the genus Culex, but that in order to convey the infection to a nonimmune individual the insect must be kept for twelve days or longer after it has filled itself with blood from a yellow fever patient in the earlier stages of the disease. In other words, that a certain period of incubation is required in the body of the insect before the germ reaches its salivary glands, and consequently before it is able to inoculate an individual with the germs of yellow fever. This inference, based upon experimental data, received support from other observations, which have been repeatedly made, with reference to the introduction and spread of yellow fever in localities favorable to its propagation. When a case is imported to one of our Southern seaport cities from Havana, Vera Cruz, or some other endemic focus of the disease, an interval of two weeks or more occurs before secondary cases are developed as a result of such importation. In the light of our present knowledge this is readily understood. A certain number of mosquitoes, having filled themselves with blood from this first case, after an interval of twelve days or more bite nonimmune individuals living in the vicinity, and these individuals, after a brief period of incubation, fall sick with the disease; being bitten by other mosquitoes they serve to transmit the disease through the "intermediate host" to still others. Thus the epidemic extends, at first slowly, as from house to house, then more rapidly, as by geometrical progression.

It will be seen that the essential difference between the successful experiments of the board of which Doctor Reed is president, and the unsuccessful experiments of Finlay consist in the length of time during which the mosquitoes were kept after filling themselves with blood from a yellow-fever patient. In Finlay's experiments the interval was usually short—from two to five or six days, and it will be noted that in the experiments of Reed and his associates the result was invariably negative when the insect had been kept for less than eight days (seven cases).

Having obtained what they considered satisfactory evidence that yellow fever is transmitted by mosquitoes, Doctor Reed and his associates proceeded to extend their experiments for the purpose of establishing the fact in such a positive manner that the medical profession and the scientific world generally might be convinced of the reliability of the experimental evidence upon which their conclusions were based. These conclusions, which have been fully justified by their subsequent experiments, were stated in their "Preliminary note" as follows:

> 1. *Bacillus icteroides* (Sanarelli) stands in no causative relation to yellow fever, but, when present, should be considered as a secondary invader in this disease.
> 2. The mosquito serves as the intermediate host for the parasite of yellow fever.

In "An additional note" read at the Pan-American Medical Congress, held in Havana, Cuba, February 4–7, 1901, a report is made of the further experiments made up to that date. In order that the absolute scientific value of these experiments may be fully appreciated, I shall quote quite freely from this report with reference to the methods adopted for the purpose of excluding all sources of infection other than the mosquito inoculation:

> In order to exercise perfect control over the movements of those individuals who were to be subjected to experimentation, and to avoid any other possible source of infection, a location was selected in an open and uncultivated field, about 1 mile from the town of Quemados, Cuba. Here an experimental sanitary station was established under the complete control of the senior member of this board. This station was named Camp Lazear, in honor of our late colleague, Dr. Jesse W. Lazear, acting assistant surgeon, United States Army, who died of yellow fever while courageously investigating the causation of this disease. The site selected was well drained, freely exposed to sunlight and winds, and from every point of view satisfactory for the purposes intended.
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> The personnel of this camp consisted of two medical officers, Dr. Roger P. Ames, acting assistant surgeon, United States Army, an immune, in immediate charge; Dr. R. P. Cooke, acting assistant surgeon, United States Army, nonimmune; one acting hospital steward, an immune; nine privates of the hospital corps, one of whom was immune, and one immune ambulance driver.
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> For the quartering of this detachment, and of such nonimmune individuals as should be received for experimentation, hospital tents, properly floored, were pro-

vided. These were placed at a distance of about 20 feet from each other, and were numbered 1 to 7, respectively.

Camp Lazear was established November 20, 1900, and from this date was strictly quarantined, no one being permitted to leave or enter camp except the three immune members of the detachment and the members of the board. Supplies were drawn chiefly from Columbia Barracks, and for this purpose a conveyance under the control of an immune acting hospital steward, and having an immune driver, was used.

A few Spanish immigrants recently arrived at the port of Havana were received at Camp Lazear from time to time while these observations were being carried out. A nonimmune person, having once left this camp, was not permitted to return to it under any circumstances whatever.

The temperature and pulse of all nonimmune residents were carefully recorded three times a day. Under these circumstances any infected individual entering the camp could be promptly detected and removed. As a matter of fact, only two persons, not the subject of experimentation, developed any rise of temperature; one, a Spanish immigrant with probable commencing pulmonary tuberculosis, who was discharged at the end of three days, and the other, a Spanish immigrant who developed a temperature of 102.6 F. on the afternoon of his fourth day in camp. He was at once removed, with his entire bedding and baggage, and placed in the receiving ward at Columbia Barracks. His fever, which was marked by daily intermissions for three days, subsided upon the administration of cathartics and enemata. His attack was considered to be due to intestinal irritation. He was not permitted, however, to return to the camp.

No nonimmune resident was subjected to inoculation who had not passed in this camp the full period of incubation of yellow fever, with one exception, to be hereinafter mentioned.

For the purpose of experimentation subjects were selected as follows: From tent No. 2, 2 nonimmunes, and from tent No. 5, 3 nonimmunes. Later, 1 nonimmune in tent No. 6 was also designated for inoculation.

It should be borne in mind that at the time when these inoculations were begun, there were only 12 nonimmune residents at Camp Lazear, and that 5 of these were selected for experiment, viz, 2 in tent No. 2 and 3 in tent No. 5. Of these we succeeded in infecting 4, viz, 1 in tent No. 2 and 3 in tent No. 5, each of whom developed an attack of yellow fever within the period of incubation of this disease. The one negative result, therefore, was in case 2—Moran—inoculated with a mosquito on the fifteenth day after the insect had bitten a case of yellow fever on the third day. Since this mosquito failed to infect case 4, three days after it had bitten Moran, it follows that the result could not have been otherwise than negative in the latter case. We now know, as the result of our observations, that in the case of an insect kept at room temperature during the cool weather of November fifteen or even eighteen days would, in all probability, be too short a time to render it capable of producing the disease.

As bearing upon the source of infection, we invite attention to the period of time during which the subjects had been kept under rigid quarantine prior to successful inoculation, which was as follows: Case 1, fifteen days; case 3, nine days; case 4, nineteen days; case 5, twenty-one days. We further desire to emphasize the fact that this epidemic of yellow fever, which affected 33.33 per cent of the nonimmune residents of Camp Lazear, did not concern the 7 nonimmunes occupying tents Nos. 1, 4, 6, and 7, but was strictly limited to those individuals who had been bitten by contaminated mosquitoes.

Nothing could point more forcibly to the source of this infection than the order of the occurrence of events at this camp. The precision with which the infection of the individual followed the bite of the mosquito left nothing to be desired in order to fulfill the requirements of a scientific experiment.

In summing up their results, at the conclusion of this report, the following statement is made:

> Out of a total of 18 nonimmunes whom we have inoculated with contaminated mosquitoes since we began this line of investigation 8, or 44.4 per cent, have contracted yellow fever. If we exclude those individuals bitten by mosquitoes that had been kept less than twelve days after contamination, and which were therefore probably incapable of conveying the disease, we have to record 8 positive and 2 negative results—80 per cent.

In a still later report (May, 1901) Doctor Reed says: "We have thus far succeeded in conveying yellow fever to twelve individuals by means of the bites of contaminated mosquitoes."

The nonimmune individuals experimented upon were all fully informed as to the nature of the experiment and its probable results, and all gave their full consent. Fortunately no one of these brave volunteers in the cause of science and humanity suffered a fatal attack of the disease, although several were very ill and gave great anxiety to the members of the board, who fully appreciated the grave responsibility which rested upon them. That these experiments were justifiable under the circumstances mentioned is, I believe, beyond question. In no other way could the fact established have been demonstrated, and the knowledge gained is of inestimable value as a guide to reliable measures of prevention. Already it is being applied in Cuba, and without doubt innumerable lives will be saved as a result of these experiments showing the precise method by which yellow fever is contracted by those exposed in an "infected locality." Some of these volunteers were enlisted men of the United States Army and some were Spanish immigrants who had recently arrived in Cuba. When taken sick, they received the best possible care, and after their recovery they had the advantage of being "immunes" who had nothing further to fear from the disease which has caused the death of thousands and tens of thousands of Spanish soldiers and immigrants who have come to Cuba under the orders of their Government or to seek their fortunes.

The experiments already referred to show in the most conclusive manner that the blood of yellow fever patients contains the infectious agent or germ to which the disease is due, and this has been further demonstrated by direct inoculations from man to man. This experiment was made by Doctor Reed, at Camp Lazear, upon four individuals, who freely consented to it, and in three of the four a typical attack of yellow fever resulted from the blood injection. The blood was taken from a vein at the bend of the elbow on the first or second day of sickness and was injected subcutaneously into the four nonimmune individuals, the amount being in one positive case 2 c. c., in one 1.5 c. c., and in one 0.5 c. c. In the case attended with a negative result, a Spanish immigrant, a mosquito inoculation also proved to be without effect, and Doctor Reed supposes that this individual "probably possesses a natural immunity from yellow fever." Doctor Reed says, with reference to these experiments:

> It is important to note that in the three cases in which the injection of the blood brought about an attack of yellow fever, careful cultures from the same blood, taken immediately after injection, failed to show the presence of Sanarelli's bacillus.

Having demonstrated the fact that yellow fever is propagated by mosquitoes, Doctor Reed and his associates have endeavored to ascertain whether it may also be propagated, as has been commonly supposed, by clothing, bedding, and other articles which have been in use by those sick with this disease. With reference to the experiments made for the solution of this question, I can not do better than to quote in extenso from Doctor Reed's paper read at the Pan-American Medical Congress in Havana. He says:

> We believe that the general consensus of opinion, both of the medical profession and of the laity, is strongly in favor of the conveyance of yellow fever by fomites. The origin of epidemics, devastating in their course, has been frequently attributed to the unpacking of trunks and boxes that contained supposedly infected clothing; and hence the efforts of health authorities, both State and national, are being constantly directed to the thorough disinfection of all clothing and bedding shipped from ports where yellow fever prevails. To such extremes have efforts at disinfection been carried in order to prevent the importation of the disease into the United States that during the epidemic season all articles of personal apparel and bedding have been subjected to disinfection, sometimes both at the port of departure and at the port of arrival, and this has been done whether the articles have previously been contaminated by contact with yellow fever patients or not. The mere fact that the individual has resided even for a day in a city where yellow fever is present has been sufficient cause to subject his baggage to rigid disinfection by the sanitary authorities.
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> To determine, therefore, whether clothing and bedding which have been contaminated by contact with yellow fever patients and their discharges can convey this disease is a matter of the utmost importance. Although the literature contains many references to the failure of such contaminated articles to cause the disease, we have considered it advisable to test by actual experiment on nonimmune human beings the theory of the conveyance of yellow fever by fomites, since we know of no other way in which this question can ever be finally determined.
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> For this purpose there was erected at Camp Lazear a small frame house consisting of one room 14 by 20 feet and known as "Building No. 1," or the "Infected clothing and bedding building." The cubic capacity of this house was 2,800 feet. It was tightly ceiled within with "tongue and-grooved" boards and was well battened on the outside. It faced to the south and was provided with two small windows, each 26 by 34 inches in size. These windows were both placed on the south side of the building, the purpose being to prevent, as much as possible, any thorough circulation of the air within the house. They were closed by permanent wire screens of 0.5 mm. mesh. In addition sliding glass sash were provided within and heavy wooden shutters without; the latter intended to prevent the entrance of sunlight into the building, as it was not deemed desirable that the disinfecting qualities of sunlight, direct or diffused, should at any time be exerted on the articles of clothing contained within this room. Entrance was effected through a small vestibule, 3 by 5 feet, also placed on the southern side of the house. This vestibule was protected without by a solid door and was divided in its middle by a wire-screen door, swung on spring hinges. The inner entrance was also closed by a second wire-screen door. In

this way the passage of mosquitoes into this room was effectually excluded. During the day and until after sunset the house was kept securely closed, while by means of a suitable heating apparatus the temperature was raised to 92° to 95° F. Precaution was taken at the same time to maintain a sufficient humidity of the atmosphere. The average temperature of this house was thus kept at 76.2° F. for a period of sixty-three days.

November 30, 1900, the building now being ready for occupancy, three large boxes filled with sheets, pillow slips, blankets, etc., contaminated by contact with cases of yellow fever and their discharges were received and placed therein. The majority of the articles had been taken from the beds of patients sick with yellow fever at Las Animas Hospital, Havana, or at Columbia Barracks. Many of them had been purposely soiled with a liberal quantity of black vomit, urine, and fecal matter. A dirty "comfortable" and much-soiled pair of blankets, removed from the bed of a patient sick with yellow fever in the town of Quemados, were contained in one of these boxes. The same day, at 6 p. m., Dr. R. P. Cooke, acting assistant surgeon, United States Army, and two privates of the Hospital Corps, all nonimmune young Americans, entered this building and deliberately unpacked these boxes, which had been tightly closed and locked for a period of two weeks. They were careful at the same time to give each article a thorough handling and shaking, in order to disseminate through the air of the room the specific agent of yellow fever, if contained in these fomites. These soiled sheets, pillowcases, and blankets were used in preparing the beds in which the members of the Hospital Corps slept. Various soiled articles were hung around the room and placed about the bed occupied by Doctor Cooke.

From this date until December 19, 1900, a period of twenty days, this room was occupied each night by these three nonimmunes. Each morning the various soiled articles were carefully packed in the aforesaid boxes and at night again unpacked and distributed about the room. During the day the residents of this house were permitted to occupy a tent pitched in the immediate vicinity, but were kept in strict quarantine.

December 12 a fourth box of clothing and bedding was received from Las Animas Hospital. These articles had been used on the beds of yellow fever patients, but in addition had been purposely soiled with the bloody stools of a fatal case of this disease. As this box had been packed for a number of days, when opened and unpacked by Doctor Cooke and his assistants, on December 12, the odor was so offensive as to compel them to retreat from the house. They pluckily returned, however, within a short time and spent the night as usual.

December 19 these three nonimmunes were placed in quarantine for five days and then given the liberty of the camp. All had remained in perfect health, notwithstanding their stay of twenty nights amid such unwholesome surroundings.

During the week, December 20–27, the following articles were also placed in this house, viz, pajamas suits, 1; undershirts, 2; nightshirts, 4; pillow slips, 4; sheets, 6; blankets, 5; pillows, 2; mattresses, 1. These articles had been removed from the persons and beds of four patients sick with yellow fever and were very much soiled, as any change of clothing or bed linen during their attacks had been purposely avoided, the object being to obtain articles as thoroughly contaminated as possible.

From December 21, 1900, till January 10, 1901, this building was again occupied by two nonimmune young Americans, under the same conditions as the preceding occupants, except that these men slept every night in the very garments worn by yellow-fever patients throughout their entire attacks, besides making use exclusively of their much-soiled pillow slips, sheets, and blankets. At the end of twenty-one nights of such intimate contact with these fomites, they also went into quarantine, from which they were released five days later in perfect health.

From January 11 till January 31, a period of twenty days, "Building No. 1" continued to be occupied by two other nonimmune Americans, who, like those who preceded them, have slept every night in the beds formerly occupied by yellow-fever patients and in the nightshirts used by these patients throughout the attack, without change. In addition, during the last fourteen nights of their occupancy of this house they have slept each night with their pillows covered with towels that had been thoroughly soiled with the blood drawn from both the general and capillary circulation, on the first day of the disease, in the case of a well-marked attack of yellow fever. Notwithstanding this trying ordeal, these men have continued to remain in perfect health.

The attempt which we have therefore made to infect "Building No. 1" and its seven nonimmune occupants, during a period of sixty-three days, has proved an absolute failure. We think we can not do better here than to quote from the classic work of La Roche.[1] This author says: "In relation to the yellow fever, we find so many instances establishing the fact of the nontransmissibility of the disease through the agency of articles of the kind mentioned, and of merchandise generally, that we can not but discredit the accounts of a contrary character assigned in medical writings, and still more to those presented on the strength of popular report solely. For if, in a large number of well-authenticated cases, such articles have been handled and used with perfect impunity—and that, too, often under circumstances best calculated to insure the effect in question—we have every reason to conclude that a contrary result will not be obtained in other instances of a similar kind; and that consequently the effect said to have been produced by exposure to those articles must, unless established beyond the possibility of doubt, be referred to some other agency."

The question here naturally arises, How does a house become infected with yellow fever? This we have attempted to solve by the erection at Camp Lazear of a second house, known as "Building No. 2," or the "Infected Mosquito Building." This was in all respects similar to "Building No. 1," except that the door and windows were placed on opposite sides of the building so as to give through-and-through ventilation. It was divided, also, by a wire-screen partition, extending from floor to ceiling, into two rooms, 12 by 14 feet and 8 by 14 feet respectively. Whereas, all articles admitted to "Building No. 1" had been soiled by contact with yellow-fever patients, all articles admitted to "Building No. 2" were first carefully disinfected by steam before being placed therein.

On December 21, 1900, at 11.45 a. m., there were set free in the larger room of this building fifteen mosquitoes—*C. fasciatus*—which had previously been contaminated by biting yellow-fever patients, as follows: 1, a severe case, on the second day, November 27, 1900, twenty-four days; 3, a well-marked case, on the first day, December 9, 1900, twelve days; 4, a mild case, on the first day, December 13, 1900, eight days; 7, a well-marked case, on the first day, December 16, 1900, five days—total, 15.

Only one of these insects was considered capable of conveying the infection, viz, the mosquito that had bitten a severe case twenty-four days before; while three others—the twelve-day insects—had possibly reached the dangerous stage, as they had been kept at an average temperature of 82° F.

At 12 noon of the same day John J. Moran—already referred to as case 2 in this report—a nonimmune American, entered the room where the mosquitoes had been freed, and remained thirty minutes. During this time he was bitten about the face and hands by several insects. At 4.30 p. m. the same day he again entered and remained twenty minutes, and was again bitten. The following day at 4.30 p. m. he, for the third time, entered the room, and was again bitten.

Case 7.—On December 25, 1900, at 6 a. m., the fourth day, Moran complained of slight dizziness and frontal headache. At 11 a. m. he went to bed, complaining of

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[1] R. La Roche: Yellow fever, vol. ii, p. 516, Philadelphia.

increased headache and malaise, with a temperature of 99.6° F., pulse 88; at noon the temperature was 100.4° F., the pulse 98; at 1 p. m., 101.2° F., the pulse 96, and his eyes were much injected and face suffused. He was removed to the yellow-fever wards. He was seen on several occasions by the board of experts and the diagnosis of yellow fever confirmed.

The period of incubation in this case, dating from the first visit to "Building No. 2," was three days and twenty-three hours. If reckoned from his last visit it was two days and eighteen hours. There was no other possible source for his infection, as he had been strictly quarantined at Camp Lazear for a period of thirty-two days prior to his exposure in the mosquito building.

During each of Moran's visits two nonimmunes remained in this same building, only protected from the mosquitoes by the wire-screen partition. From December 21, 1900, till January 8, 1901, inclusive—eighteen nights—these nonimmunes have slept in this house, only protected by the wire-screen partition. These men have remained in perfect health to the present time.

Thus at Camp Lazear of 7 nonimmunes whom we attempted to infect by means of the bites of contaminated mosquitoes we have succeeded in conveying the disease to 6, or 85.71 per cent. On the other hand, of 7 nonimmunes whom we tried to infect by means of fomites, under particularly favorable circumstances, we did not succeed in a single instance.

It is evident that in view of our present knowledge relating to the mode of transmission of yellow fever, the preventive measures which have heretofore been considered most important—i. e., isolation of the sick, disinfection of clothing and bedding, and municipal sanitation—are either of no avail or of comparatively little value. It is true that yellow-fever epidemics have resulted, as a rule, from the introduction to a previously healthy locality of one or more persons suffering from the disease. But we now know that its extension did not depend upon the direct contact of the sick with nonimmune individuals and that isolation of the sick from such contact is unnecessary and without avail. On the other hand, complete isolation from the agent which is responsible for the propagation of the disease is all-important. In the absence of a yellow-fever patient from which to draw blood the mosquito is harmless, and in the absence of the mosquito the yellow-fever patient is harmless, as the experimental evidence now stands. Yellow-fever epidemics are terminated by cold weather because then the mosquitoes die or become torpid. The sanitary condition of our southern seaport cities is no better in winter than in summer, and if the infection attached to clothing and bedding it is difficult to understand why the first frosts of autumn should arrest the progress of an epidemic. But all this is explained now that the mode of transmission has been demonstrated.

Insanitary local conditions may, however, have a certain influence in the propagation of the disease, for it has been ascertained that the species of mosquito which serves as an intermediate host for the yellow-fever germ may breed in cesspools and sewers as well as in stagnant pools of water. If, therefore, the streets of a city are unpaved and ungraded, and there are open spaces where water may accumulate in pools, as well as open cesspools to serve as breeding places for *Culex fasciatus*, that city will present conditions more favorable for the propagation of yellow fever than it would if well-paved and drained and sewered.

The question whether yellow fever may be transmitted by any other species of mosquito than *Culex fasciatus* has not been determined. Facts relating to the propagation of the disease indicate that the mosquito which serves as an intermediate host for the yellow-fever germ has a somewhat restricted geographical range and is to be found especially upon the seacoast and the margins of rivers in the so-called "yellow-fever zone." While occasional epidemics have occurred upon the southwest coast of the Iberian peninsula, the disease, as an epidemic, is unknown elsewhere in Europe, and there is no evidence that it has ever invaded the great and populous continent of Asia. In Africa it is limited to the west coast. In North America, although it has occasionally prevailed as an epidemic in every one of our seaport cities as far north as Boston, and in the Mississippi Valley as far north as St. Louis, it has never established itself as an endemic disease within the limits of the United States. Vera Cruz, and probably other points on the Gulf coast of Mexico, are, however, at the present time endemic foci of the disease. In South America it has prevailed as an epidemic at all of the seaports on the Gulf and Atlantic coasts, as far south as Montevideo and Buenos Ayres, and on the Pacific along the coast of Peru.

The region in which the disease has had the greatest and most frequent prevalence is bounded by the shores of the Gulf of Mexico, and includes the West India Islands. Within the past few years yellow fever has been carried to the west coast of North America, and has prevailed as an epidemic as far north as the Mexican port of Guaymas, on the Gulf of California.

It must not be supposed that *Culex fasciatus* is only found where yellow fever prevails. The propagation of the disease depends upon the introduction of an infected individual to a locality where this mosquito is found, at a season of the year when it is active. Owing to the short period of incubation (five days or less), the brief duration of the disease, and especially of the period during which the infectious agent (germ) is found in the blood, it is evident that ships sailing from infected ports, upon which cases of yellow fever develop, are not likely to introduce the disease to distant seaports. The continuance of an epidemic on shipboard, as on the land, must depend upon the presence of infected mosquitoes and of nonimmune individuals. Under these conditions we can readily understand why the disease should not be carried from the West Indies or from South America to the Mediterranean, to the east coast of Africa, or to Asiatic seaport cities. On the other hand, if the disease could be transmitted by infected clothing, bedding, etc., there seems no good reason why it should not have been carried to these distant localities long ago.

The restriction as regards altitude, however, probably depends upon the fact that the mosquito which serves as an intermediate host is a coast species, which does not live in elevated regions. It is a well-established fact that yellow fever has never prevailed in the City of Mexico, although this city has constant and unrestricted intercourse with the infected seaport, Vera Cruz. Persons who have been exposed in Vera Cruz during the epidemic season frequently fall sick after their arrival in the City of Mexico, but they do not communicate the disease to those in attendance upon them or to others in the vicinity. Evidently some factor essential for the propagation of the disease is absent, although we have the sick man, his clothing and bedding and the insanitary local conditions which have been supposed to constitute an essential factor. I am not aware that any observations have been made with reference to the presence or absence of *Culex fasciatus* in high altitudes, but the inference that it is not to be found in such localities as the City of Mexico seems justified by the established facts already referred to.

As pointed out by Hirsch, "the disease stops short at many points in the West Indies where the climate is still in the highest degree tropical." In the Antilles it has rarely appeared at a height of more than 700 feet. In the United States the most elevated locality in which the disease has prevailed as an epidemic is Chattanooga, Tenn., which is 745 feet above sea level.

It will be remembered that the malarial fevers are contracted as a result of inoculation by mosquitoes of the genus Anopheles, and that the malarial parasite has been demonstrated not only in the blood of those suffering from malarial infection, but also in the stomach and salivary glands of the mosquito. If the yellow fever parasite resembled that of the malarial fevers it would no doubt have been discovered long ago, but as a matter of fact this parasite, which we now know is present in the blood of those sick with the disease, has thus far eluded all researches. Possibly it is ultramiscroscopic. However this may be, it is not the only infectious-disease germ which remains to be discovered. There is without doubt a living germ in vaccine lymph and in the virus from smallpox pustules, but it has not been demonstrated by the microscope. The same is true of foot-and-mouth disease and of infectious pleuro-pneumonia of cattle, although we know that a living element of some kind is present in the infectious material by which these diseases are propagated. In Texas fever of cattle, which is transmitted by infected ticks, the parasite is very minute, but by proper staining methods and a good miscroscope it may be detected in the interior of the red blood corpuscles. Doctors Reed and Carroll are at present engaged in a search for the yellow fever germ in the blood and in the bodies of infected mosquitoes. What success may attend their efforts remains to be seen, but at all events the fundamental facts have been demonstrated that this germ is present in the blood, and that the disease is transmitted by a certain species of mosquito—*C. fasciatus.*

The proper measures of prophylaxis, in view of this demonstration, are given in the following circular, which was submitted for my approval by the chief surgeon, Department of Cuba, and has recently been published by the commanding general of that department, who, until quite recently, was a member of the Medical Corps of the Army.

CIRCULAR, }
No. 5. }
HEADQUARTERS DEPARTMENT OF CUBA,
Havana, April 27, 1901.

Upon the recommendation of the chief surgeon of the department, the following instructions are published and will be strictly enforced at all military posts in this department:

The recent experiments made in Havana by the Medical Department of the Army having proved that yellow fever, like malarial fever, is conveyed chiefly, and probably exclusively, by the bite of infected mosquitoes, important changes in the measures used for the prevention and treatment of this disease have become necessary.

1. In order to prevent the breeding of mosquitoes and protect officers and men against their bites, the provisions of General Orders, No. 6, Department of Cuba, December 21, 1900, shall be carefully carried out, especially during the summer and fall.

So far as yellow fever is concerned, infection of a room or building simply means that it contains infected mosquitoes; that is, mosquitoes which have fed on yellow fever patients. Disinfection, therefore, means the employment of measures aimed at the destruction of these mosquitoes. The most effective of these measures is fumigation, either with sulphur, formaldehyde, or insect powder. The fumes of sulphur are the quickest and most effective insecticide, but are otherwise objectionable. Formaldehyde gas is quite effective if the infected rooms are kept closed and sealed for two or three hours. The smoke of insect powder has also been proved very useful; it readily stupefies mosquitoes, which drop to the floor and can then be easily destroyed.

The washing of walls, floors, ceilings, and furniture with disinfectants is unnecessary.

3. As it has been demonstrated that yellow fever can not be conveyed by fomites, such as bedding, clothing, effects, and baggage, they need not be subjected to any special disinfection. Care should be taken, however, not to remove them from the infected rooms until after formaldehyde fumigation, so that they may not harbor infected mosquitoes.

Medical officers taking care of yellow-fever patients need not be isolated; they can attend other patients and associate with nonimmunes with perfect safety to the garrison. Nurses and attendants taking care of yellow-fever patients shall remain isolated, so as to avoid any possible danger of their conveying mosquitoes from patients to nonimmunes.

4. The infection of mosquitoes is most likely to occur during the first two or three days of the disease. Ambulant cases—that is, patients not ill enough to take to their beds and remaining unsuspected and unprotected—are probably those most responsible for the spread of the disease. It is therefore essential that all fever cases should be at once isolated and so protected that no mosquitoes can possibly get access to them until the nature of the fever is positively determined.

Each post shall have a "reception ward" for the admission of all fever cases and an "isolation ward" for the treatment of cases which prove to be yellow fever. Each ward shall be made mosquito-proof by wire netting over doors and windows, a ceiling of wire netting at a height of 7 feet above the floor, and mosquito bars over the beds. There should be no place in it where mosquitoes can seek refuge, not readily accessible to the nurse. Both wards can be in the same building, provided they are separated by a mosquito-tight partition.

5. All persons coming from an infected locality to a post shall be kept under careful observation until the completion of five days from the time of possible infection, either in a special detention camp or in their own quarters; in either case their temperature should be taken twice a day during this period of observation, so that those who develop yellow fever may be placed under treatment at the very inception of the disease.

6. Malarial fever, like yellow fever, is communicated by mosquito bites, and therefore is just as much of an infectious disease and requires the same measures of protection against mosquitoes. On the assumption that mosquitoes remain in the vicinity of their breeding places, or never travel far, the prevalence of malarial fever at a post would indicate want of proper care and diligence on the part of the surgeon and commanding officer in complying with General Orders, No. 6, Department of Cuba, 1900.

7. Surgeons are again reminded of the absolute necessity, in all fever cases, to keep, from the very beginning, a complete chart of pulse and temperature, since such a chart is their best guide to a correct diagnosis and the proper treatment.

By command of Major-General Wood:

H. L. Scott, *Adjutant-General.*

PSYCHICAL RESEARCH OF THE CENTURY.[1]

By Andrew Lang.

It is difficult even to give a name to the subject of this essay. The word "psychical" seems to beg the question, and to insinuate that there is such a thing as a *psyche*, or soul, distinguished from the ordinary intellect. As a matter of fact, psychical research is only an inquiry as to whether there be any faculties and phenomena to which, for lack of a better name, the term "psychical" may be applied. That there are such faculties and such phenomena has been the belief of the majority of mankind in all known ages. A singular uniformity marks the beliefs (or superstitions) of all periods, races, and conditions of culture. This uniformity, of course, does not, as Dr. Johnson inferred, amount to proof. Curiosity and love of excitement, wearied with the "natural" (that is, accustomed) round of events, had only to imagine exceptions to everything nórmal; and "miracles" of uniform character were at once asserted. A dead man does not walk about; deny this—and ghosts walk. People can not be in two places at once; deny this—and you have "bilocation." Men do not fly; deny this—and you have "levitation." The future and the remote are dark to all; deny this—and you invent every branch of prophecy, seership, and clairvoyance. Inanimate objects are never spontaneously volatile; affirm the opposite—and you are confronted with the "physical phenomena" of "spiritualism." Fire always burns objects subjected to its action; affirm the opposite—and you come to Shadrach, Meshach, and Abednego. Thus the uniformity of the beliefs in such marvels is very readily explained.

But the explanation becomes more difficult when you have to deal, not with savage mythology and civilized folk-lore, but with the attested experiences of educated modern men and women. They have witnessed one or other of these marvels, or so they persist in averring. Their experience has been identical with that of savages and barbarians; with that of classical antiquity; with that of saints, witches, and members of the Royal Society at the time of the Restoration. This fact is so puzzling that, at different periods,

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educated persons have investigated the evidence for the reported marvels. In the Alexandria of the fourth Christian century, Porphyry; in the England of Charles II, Glanvill, More, Baxter, and Boyle; in the America of 1680–1720, the Mathers; in the Germany of 1760–1830, Kant and Hegel; in the France of 1780–1830, various learned bodies, took part in these investigations. Little that can be relied on was discovered. The researches were usually unmethodical, often prejudiced, often superstitious. Only in the last twenty years has inquiry been methodical, skeptical, and persistent. The practices of Mesmer at the end of the eighteenth century opened the way. They interested, in the nineteenth century, the Schellings, Hegel, and Ritter. Hegel believed in clairvoyance, in what is called telepathy (the action of distant mind on distant mind, through no known channel of sense), and in the divining-rod. For all these things he found a place in his "Philosophy of Spirit." The theory which explains what we call facts of hypnotism by "animal magnetism" was accepted, or at least many of the marvels of this kind were accepted, in a report of a scientific French committee in 1831. But the report was burked, and the topic was banished to keep company with the origin of language and the squaring of the circle. Yet the topic kept recurring, and the "magnetic sleep" was vouched for by Dr. Elliotson. About 1841–1845, Braid of Manchester introduced the word "hypnotism," to cover the phenomena of induced somnambulism. He proved that the old theory of a magnetic efflux from the operator was superfluous, and that the sleep, with all its peculiarities of hallucination and of submission to the will, could be induced in a variety of mechanical ways. The patient could be made insensible to pain, and only the introduction of chloroform checked the use of hypnotism in surgical operations. It was also shown that the mind of the hypnotic patient could be so influenced as to affect his body, and, at least in nervous and hysterical diseases, to exercise a healing influence. These discoveries, obviously, explain many of the stories of witchcraft, of healing miracles, and of "glamour," or the induced false perceptions, which were part of the stock in trade of conjurers in the Middle Ages and the seventeenth century.

So far, I think, these inquiries have undeniably reached solid ground, and have cleared up the obscure subject of witchcraft. The only question is one of degree. How far are the stranger phenomena of hypnotism, such as the suggestion of sleep from a distance, based on good evidence? In the middle of the century Drs. Gregory and Mayo, in two interesting works, investigated the amount of truth involved in popular superstitions. They accepted clairvoyance and successful crystal-gazing, that world-wide practice. Meanwhile, many physicians and others worked at the topic of hallucinations of the senses, both in the sane and the insane. A few of them brought forward cases of premonitory dreams and telepathic incidents, which they professed to be unable to explain away. The subjects of a certain Major Buckley (1840–1850) were deemed to be peculiarly clairvoyant, and the anecdotes, in one or two cases, have good evidence. The case of "Queen Mary's Jewels" (criticised in my "Book of Dreams and Ghosts") has, at all events, romantic historical interest. In 1848 a very old set of beliefs was moved into new life. The noises and disturbances in the family of the Foxes at Hydeville were only a link in an historic chain of similar alleged occurrences. They are of rather more than dubious authenticity, but they were the beginning of modern "Spiritualism," with numberless impostures. The chief thaumaturge and prophet of the movement was Daniel Dunglas Home (his palmy years were 1855–1865), who had a singular career of social and magical successes in the courts and literary society of Europe. Few feats of savage, or Neoplatonic, or saintly wonder-workers were absent from his repertoire, and living men of the highest eminence in physical science are still wholly unable to explain what they saw of his performances. I have known but one case in which, on first-hand evidence, imposture was attributed to him. But a jury practically found him guilty of cajoling a silly old woman out of her money. That is the blot on Home's escutcheon; for the rest, the great mass of unpublished letters to him from many distinguished correspondents attest his inexplicable success. He was not a clever man, and, had he not been a "medium," would have been a reciter and musician of the drawing-room. Other "mediums" on the same lines have been numerous; few, if any, professionals have escaped exposure. Meanwhile, the theory of the feats, that they are caused by "spirits," is now almost confined to the half educated.

Much, at this time, was written about "table turning." This is a form of automatism familiar to most savage races. A person, or persons, touch a table, a stick, a pencil, or what not; the thing moves under no conscious muscular action of theirs, and gives responses to questions by its movements, in a variety of ways. These responses are sometimes correct, though unknown to the operators. Dr. Carpenter explained these things by a theory of "unconscious cerebration." Every one will admit that many things are registered in the mind of which the ordinary consciousness is not aware. Many things once present to consciousness are forgotten. Again, a person speaks to you when your mind is engaged. You know nothing, consciously, of what has been said, yet it is registered in the brain. The theory, then, is that the "unconscious," or "subliminal," or "subconscious" self expresses its knowledge through unconsciously exerted muscular movements. But the phenomena were often ascribed to the action of "spirits." The philosophy of the unconscious, or subconscious, studied by Kant and brought to England by Sir William Hamilton, had not attracted attention in England. Psychical research, investigating automatic actions, has enlarged our knowledge of this obscure topic.

After the "spiritualistic" wave had expended itself, at least among the educated, a society was formed in England, "The Society for Psychical Research," to investigate the whole mass of reported supernormal phenomena. The founders, about 1880, were a group of Cambridge scholars, the late Mr. Edmund Gurney, Mr. Frederick, and Mr. Arthur Myers, the late Professor Sidgwick, Mr. Podmore, and others. Many men of science, such as Sir William Crookes, Prof. Balfour Stewart, Prof. Oliver Lodge, the late distinguished electrician, Professor Hertz, with Lord Tennyson, Mr. A. J. Balfour, M. P., Mr. Gladstone, and a number of British and continental savants, lent their names and a portion of their energy to the society. In the American branch Prof. William James, with others, represents official psychology. The object of the society was to collect and cross-examine first-hand evidence for the ancient alleged phenomena called "ghosts," "wraiths," "haunted houses," clairvoyance, premonitions, "spiritualistic disturbances," and so forth. The society thought that ideas of such old standing and wide diffusion, and reported modern experiences in the same kind, ought to be scientifically examined. Experiments were also to be made. The leaders were men familiar with the science of psychology and of the brain. Mr. Myers and Mr. Gurney especially conducted a long and careful series of experiments in hypnotism. Mr. Gurney published a very learned essay on "Hallucinations of the Senses." Meanwhile Mr. Gurney, especially, with Mr. Myers, Mr. Podmore, and Mr. and Mrs. Sidgwick, collected all available first-hand evidence for "ghosts" of the dead and "wraiths" of the living or dying. The personal examination of witnesses and of corroborative evidence was pursued with minute and conscientious care.

Moreover, many experiments were made in "thought transference." One person, say, thinks of a diagram, a picture, a card, or what not, which another person, carefully excluded from sensible contact with the first, endeavors to reproduce. The results often seemed highly successful, and experience enabled the experimenters to discover and eliminate such causes as "unconscious whispering," as well as to detect some methods of fraud. Having convinced themselves that the transference of thought, not by any recognized channels of the senses, was a possibility, even when the experimenters were not in the same room, the investigators applied their discovery to their great collection of "ghosts" and "wraiths." The results were published in two large volumes, called "Phantasms of the Living." The argument, put briefly, was that the mind or brain of a person in a crisis, notably in the crisis of death, could affect by visual, audible, or other hallucinations of various kinds and degrees the mind or brain of another person at a distance. This was a mere development of the idea of voluntary and experimental thought transference by no recognized channel of sense. These conclusions, if accepted, account for the universal belief in death wraiths. But of course an obvious difficulty arises. Many sane and temperate people have had experience of the hallucination that a distant person is present, when that person turns out to have been in perfect health and in no crisis at all. Therefore, we must ask, Do the hallucinations which coincide with a death or other crisis coincide by mere accident and so afford no evidence for the action of mind on distant mind? Without an enormous census, this question can not be decided. The society, however, collected more than 17,000 answers to a list of questions, and the committee satisfied themselves that, on this body of testimony, the hallucinatory appearances coincided with the death of the person who seemed to appear 440 times more often than ought to be the case by the law of probabilities. They pronounced that "between deaths and apparitions of the dying a connection exists which is not due to chance alone." This position has been attacked by Dr. Parish in his "Hallucinations and Illusions."

The society, as a society, expresses no opinion, but the committee of the society, for their part, decided that "wraiths" are coincidental, or veridical, hallucinations produced by some unknown mental or cerebral process, called, provisionally, "telepathy"—sensation from a distance. Whether the process is "physical," and caused by the molecular action of one brain upon another distant and recipient brain (as in "wireless telegraphy"), or whether the process is "psychical," and involves the action of a mysterious psychical faculty, there is no means of deciding. But if we admit that there are phantasms of the dead, not being mere casual hallucinations, then we must conceive the process to be psychical: the *brain* of the dead being dust, the "soul" must be the agent. Of phantasms of the dead or "ghosts," the society has collected numerous examples at first hand. On the hypothesis already explained, these appearances would be caused by the action of the disincarnate upon the living mind. But how can it be proved that the phantasm is no mere empty hallucination or illusion, begotten subjectively by grief, by association of ideas, or by a casual arrangement of light and shade? We have in the case of the dead no coincidental crisis of their own to appeal to, as in the case of phantasms of the living. The only possible test is the communication by the phantasm of knowledge otherwise unattainable by the percipient.

The modern ghost seldom speaks, and the knowledge is indirectly communicated. One or two examples are needed. Thus, residing in a house in Switzerland, a lady saw a phantasm exactly like the portraits of Voltaire. She then learned, for the first time, that she occupied what had been Voltaire's room. But had she not known about

Voltaire's connection with the house, and forgotten? Again, a young American, when making up his books in a hotel, sees the phantasm of his dead sister, with a long scratch on her cheek. His mother tells him what she had kept secret, that she herself accidentally scratched the cheek of the corpse, as she arranged flowers in the coffin, and that she concealed it by aid of powder. But, granting telepathy, was not the phantasm a projection from the mind of the mother, who knew the fact? It is plain that telepathy, if accepted, makes it almost impossible for a ghost to prove his identity. He can do this only by communicating knowledge contained in no incarnate mind, but afterwards discovered to exist in some long-lost document or other source of evidence. The nearest approach known to me to such a thing is in the case of Queen Mary's secret jewels. Gregory published a "vision" of these jewels, with many attendant circumstances, beheld by a hypnotized young man. Several years later was discovered, in a heap of old law papers in the Scottish Register House, an inventory of Queen Mary's jewels. Still later the inventory was published by Dr. Joseph Robertson. I compared the inventory with the account of the vision and the results were, to a considerable degree, corroborative. But corroboration of this kind, in the nature of the case, must be very rare.

Thus any knowledge contributed by a seeming phantasm of the dead may be explained away by a sweeping theory of telepathy. The phantasm makes you aware of this or that fact, which is verified. But, if the verifying evidence may conceivably have become known, say to a German savant working in the Sultan's library, then it may be urged that the German savant unconsciously "wired on" his information to you in the shape of an hallucination. This theory is not easily accepted, but it may be more credible than the hypothesis of an hallucination caused by a disincarnate mind.

As to "haunted houses," the society has occupied many, to little purpose. Ghosts, indeed, are seen, and astonishing noises are heard by such members of the investigating parties as are in the way of experiencing hallucinations wherever they go. But that proves nothing. I myself stayed for a week in a "haunted house," whence the noises had evicted a large shooting party, but nothing beyond the normal swam into my ken. To be sure, I had asked for as quiet a room as possible—I certainly got it. As far as the researches of the society go, the ghosts retreat before them, whereas, on the theory that the society are superstitious fools, they ought to see ghosts in exceeding abundance by dint of expectation. It would appear that haunted houses are local centers of a permanent possibility of hallucination. Thus in an old house at St. Andrews a cheerful family last year constantly met an unknown lady on the stairs. She always went into the same room, but never was found there when pursued. The cheerful family regarded her as a pleasing peculiarity of the mansion. This anecdote leads to the difficult topic of "collective hallucination," as when a number of persons similarly situated are similarly and simultaneously hallucinated. The causes remain a puzzle. Are all affected by an external cause or does one person "wire on" his hallucinations to the others?

It will be observed that this theory of hallucination gets rid of the old puzzle: "How about the clothes of the ghost?" Clothes have no ghosts, yet I have heard of only one ghost without clothes (on the evidence of the report of a criminal trial in 1753). The new theory simply explains that there is neither ghost nor clothes in the case; the hallucination merely includes clothes for the sake of decency or because the agent, the mind which affects the percipient's mind, thinks of himself as dressed "in his habit as he lived."

While the society, advancing from the experimental thought transference to telepathy, has more or less explained "wraiths" and has perhaps suggested a conceivable theory of "ghosts" in the region of spiritualistic material phenomena, as of volatile articles of furniture, it has found no certainty. Experiments with paid "mediums" have invariably resulted in the detection of imposture, notably in the case of Slade and of Eusapia Paladino. But it is fair to say that some thinkers even now believe that Eusapia occasionally gets her effects without cheating. In the cases of amateur mediums many things told on evidence unimpeachable in worldly matters are certainly hard to explain. For a number of years a Mrs. Piper, a citoyenne of the United States, has been closely studied by the learned, as by Prof. William James, Dr. Hodgson, and Prof. Oliver Lodge. Her specialty is to convey, by writing or word of mouth, "messages from the dead." Vast reports on Mrs. Piper have been edited by Dr. Hodgson, certainly a clear-headed and skeptical observer, who exposed Eusapia Paladino and Madame Blavatsky. As at present advised, Dr. Hodgson expresses his belief that the dead do communicate through Mrs. Piper. Others hold that the "communicators" are only "secondary personalities" of the lady, and that when she does hit on facts not normally knowable by her she owes the information to telepathy. How is the reverse to be proved? How can she communicate matter at once capable of verification and yet unknown to any living mind? This is the old difficulty which besets spirits of the dead.

On the whole, psychical research has, I think, shown that there is a real element of obscure mental faculty involved in the "superstitions" of the past and present. It has also made some discoveries of practical value in hypnotism and the treatment of hysteria. It strengthens the opinion that science has not yet exhausted all attainable knowledge about the constitution of man.

THE NEW SPECTRUM.

By S. P. Langley.[1]

The writer (at the concluding meeting of the National Academy of Sciences on April 18) remarked on the disadvantages in the matter of interest of the work of the physicist, which he was about to show them, to that of the biologist, which was concerned with the ever absorbing problem of life. He had, however, something which seemed to him of interest, even in this respect, to speak of, for it included some indications he believed to be new, pointing the way to future knowledge of the connection of terrestrial life with that physical creator of all life, the sun.

He had to present to the academy a book embodying the labor of twenty years, though at this late hour he could scarcely more than show the volume with a mention of the leading captions of its subject. What he had to say then would be understood as only a sort of introductory description of the contents of the work in question, which was entitled "Volume I of the Annals of the Astrophysical Observatory of the Smithsonian Institution."

In illustration of a principal feature of this book, the academy saw before them on the wall an extended solar spectrum, only a small portion of the beginning of which, on the left, was the visible spectrum known to Sir Isaac Newton. This was the familiar visible colored spectrum which we all have seen and know something of, even if our special studies are in other fields.

It is chiefly this visible part, which has been hitherto the seat of prolonged spectroscopic investigation, from a little beyond the violet, at a wave-length of somewhat less than 0.4^{μ} down to the extreme red, which is generally considered to terminate at the almost invisible line A, whose wave-length is 0.76^{μ}. On the scale of the actual wave-length of light, then, where the unit of measurement (1^{μ}) is one one-thousandth of a millimeter, the length of the visible spectrum is 0.36^{μ}.

The undue importance which this visible region has assumed, not only in the eyes of the public, but in the work of the spectroscopist, is easily intelligible, being due primarily to the evident fact that we all

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[1] Abstract of a paper read before the National Academy of Sciences at its Washington meeting April 18, 1901.

possess, as a gift from nature, a wonderful instrument for noting the sun's energy in this part, and in this part only.

While, then, this part alone can be *seen* by all, yet the idea of its undue importance is also owing to the circumstance that the operation of the ordinary prism gives an immensely extended linear depiction of the really small amount of energy in this visible part. There is also a region beyond the violet, most insignificant in energy and invisible to the eye, and the association of this linear extension due to the prism, with the accident that the salts of silver used in photography are extraordinarily sensitive to these short wave-length rays, so that they can depict them even through the most extreme enfeeblement of the energy involved in producing them, also makes this part have undue prominence. This action of the prism and of the photograph is local, then, and peculiar to the short wave-lengths; and owing to it, all but special students of the subject are, as a rule, under a wholly erroneous impression of the relative importance of what is visible and what is not. The spectrum has really no positive dimension, being extended at one end or the other according to the use of the prism or grating employed in producing it. Perhaps the only fair measurement for displaying a linear representation of the energy would be that of a special scheme, which the writer had proposed, in which the energy is everywhere the same;[1] but this presentation is unusual and would not be generally intelligible without explanation.

The map before us will be intelligible when it is stated that it is, as to the infra-red, an exact representation of that part of the spectrum given by a rock-salt prism. The visible and ultra-violet spectrum given here is not exact, for the reason that it would take nearly a hundred *feet* of map to depict it on the prismatic scale, though this is caused by but a small fraction of the sun's energy; so monstrous is the exaggeration due to the dispersion of the prism.

Looking, then, at the map: First, in the spectrum on the left and beyond 0.4^μ is the ultra-violet region, in fact almost invisibly small, but which in most photographs shows almost a *hundred times larger than the whole infra-red.* It really contains much less than one-hundredth part of the total solar energy which exists. Beyond it is the visible spectrum, containing perhaps one-fifth the solar energy.

As the writer has elsewhere said, "the amount of energy in any region of the spectrum, such as that in any color, or between any two specified limits, is a definite quantity, fixed by facts, which are independent of our choice, such as the nature of the radiant body or the absorption which the ray has undergone. Beyond this Nature has no law which must govern us."

Everything in the linear presentation, then, depends on the scale adopted. In other words, if we have the lengths proportionable to the

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[1] American Journal of Science, III, xxvii, p. 169, 1884.

energies, the familiar prismatic representation enormously exaggerates the importance of the visible, and still more of the ultra-violet region, and similarly the grating spectrum exaggerates that of the infra-red region. Now he had given, on the map before them, and through the whole infra-red, the exact rock salt prismatic spectrum, but for the purpose of obtaining a length which represented (though insufficiently) that of the visible spectrum, he had laid the latter down on the *average* dispersion in the infra-red, which was perhaps as fair a plan as could be taken for showing the approximate relation of the two fields of energy in an intelligible way, though it gave the visible energy too small.

Let us recall, then, at the risk of iteration, that in spite of the familiar extended photographic spectra of the hundreds of lines shown in the ultra-violet, and in those of the colored spectrum, it is not here that the real creative energy of the sun is to be studied, but elsewhere, on the right of the drawing, in the infra-red. Looking to the spectrum as thus delineated, next to the invisibly small and weak ultra-violet, comes the visible or Newtonian spectrum, which is here somewhat insufficiently shown, and on the right extends the great invisible spectrum in which four-fifths of the solar energies are now known to exist.

Of this immense invisible region nothing was known until the year 1800,[1] when Sir William Herschel found heat there with the thermometer.

After that little was done[2] (except an ingenious experiment by Sir John Herschel[3] to show that the heat was not continuous) till the first drawing of the energy curve by Lamansky,[4] in 1871, which, on account of its great importance in the history of the subject, is given on the map. It consists of the energy curves of the visible spectrum, and beyond it, on the right (and in illustration of what has just been said it will be seen how relatively small these latter appear), of three depressions indicating lapses of heat in the infra-red. It is almost impossible to tell what these lapses are meant for, without a

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[1] Philosophical Transactions, vol. xc, p. 284, 1800.

[2] It should, however, be mentioned that an important paper by Draper (London, Ed. Dublin Phil. Mag., May, 1843) was published in 1843, in which he appears to claim the discovery of the group here called $\rho\sigma\tau$ and which is now known to have a wave-length of less than 1^{μ}. (Its true wave-length was not determined till much later.) Later, Fizeau seems to have found further irregularities of this heat as long ago as 1847, and of its location, obtaining his wave-lengths by means of interference bands. His instrumental processes, though correct in theory, were not exact in practice; and yet it seems pretty clear that he obtained some sort of recognition of a something indicating heat, as far down as the great region immediately above Ω on our present charts. Mouton (Comptes Rendus, 1879) confirmed this observation of Fizeau's and contrived to get at least an approximate wave-length of the point where the spectrum (to him) ended, at about 1.8^{μ}.

[3] Philosophical Transactions, vol. cxxx, p. 1, 1840.

[4] Monatsberichte der k. Akademie der Wissenschaften zu Berlin, December, 1871.

scale of some kind (which he does not furnish), but they probably indicate something, going down to near a wave-length of 1^{μ}. It is obvious that the detail is of the very crudest, and yet this drawing of Lamansky's was remarkable as the first drawing of the energy spectrum. It attracted general attention, and was the immediate cause of the writer's taking up his researches in this direction.

It seems proper to state here that the true wave-lengths were at that time most imperfectly known, but that in 1884, and later in 1885,[1] they were completely determined by the writer as far as the end of what he has called "the new spectrum" at a wave-length of 5.3^{μ}.

The upper portion of the infra-red is quite accessible to photography, and the next important publication in this direction was that of Captain (now Sir William) Abney,[2] which gave the photographic spectrum down to about 1.1^{μ}, much beyond which photography has never mapped since.

From the time of seeing Lamansky's drawing, the writer had grown interested in this work, but found the thermopile, the instrument of his predecessors, and the most delicate then known to science, insufficient in the feeble heat of the grating spectrum, and about 1880 he had invented the bolometer[3] and was using it in that year for these researches. This may perhaps seem the place to speak of this instrument, though with the later developments which have made it what it is to-day, it has grown to something very different from what it was then.

It has, in fact, since found very general acceptance among physicists, especially since it has lately reached a degree of accuracy, as well as of delicacy, which would have appeared impossible to the inventor himself in its early days.

It may be considered in several relations, but notably as to three: (1) Its sensitiveness to small amounts of heat; (2) the accuracy of measurement of those small amounts; and (3) the accuracy of its measurements of the position of the source of heat.

As to the first, it is well known that the principle of the instrument depends on the forming of a Wheatstone bridge, by the means of two strips of platinum or other metal, of narrow width and still more limited thickness, one of which only is exposed to the radiation. In some bolometers in use, for instance, the strip is a tenth of a millimeter, or one two-hundred-and-fiftieth of an inch in width; and yet it is to be described as only a kind of tape, since its thickness is less than a tenth of this.

The use of the instrument is then based on the well-known fact that the heating of an ordinary metallic conductor increases its resistance,

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[1] American Journal of Science, March, 1884, and August, 1886.

[2] Philosophical Transactions, vol. clxxi, p. 653, 1880.

[3] Actinic balance, American Journal of Science, 3d series, vol. xxi, p. 187, 1881.

and this law is found to hold good in quantities so small that they approach the physically infinitesimal. In the actual bolometers, for instance, the two arms of a Wheatstone bridge are formed of two strips of platinum, side by side, one of which is exposed to the heat and the other sheltered. The warming of the exposed one increases its resistance and causes a deflection of the galvanometer.

It was considered to be remarkable twenty years ago that a change of temperature of one ten-thousandth of a degree Centigrade could be registered; it is believed at present that with the consecutive improvements of the original instrument and others, including those which Mr. Abbot, of the Smithsonian Institution Observatory, has lately introduced into its attendant galvanometer, less than one *one-hundred-millionth* of a degree in the change of temperature of the strip can be registered. This indicates the sensitiveness of the instrument to heat.

As to the second relation, some measures have been made on the steadiest light source obtainable. With ordinary photometric measures of its intensity one might expect a probable error of about 1 per cent. The error with the bolometer was insensible by any means that could be applied to test it. It is at any rate less than two one-hundredths of 1 per cent. If we imagine an absolutely invisible spectrum, in which there nevertheless are interruptions of energy similar to those which the eye shows us in the visible, then the bolometer, whose sensitive strip passes over a dark line in the spectrum, visible or invisible (since what is darkness to the eye is cold to it), gives a deflection on the side of cold, and in the warmer interval between two lines a deflection on the side of heat; these deflections being proportionate to the cause, within the degree of accuracy just stated.

The third quality, the accuracy of its measures of position, is better seen by a comparison and a statement, for if we look back to the indications of the lower part of Lamansky's drawing we may see that at least a considerable fraction of a degree of error must exist there in such a vague delineation. Now, in contrast with this early record, the bolometer has been brought to grope in the dark and to thus feel the presence of narrow Fraunhofer-like lines by their cooler temperature alone, with an error of the order of that in refined astronomical measurement; that is to say, the probable error, in a mean of six observations of the relative position of one of these invisible lines, is less than one second of arc; a statement which the astronomer, perhaps, who knows what an illusive thing a second of arc is, can best appreciate.

The results of the writer's labors with the bolometer in the years 1880 and 1881, and in part of his expedition in the latter year to Mount Whitney, were given at the Southampton meeting of the British Association for the Advancement of Science in 1882.[1] During these two

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[1] Report British Association, 1882. Nature xxvi, 1882.

years very many thousand galvanometer readings were taken, by a most tryingly slow process, to give the twenty or more interruptions shown at that time, below the limit of 1.1^μ of Abney's photographs. The bolometer has been called an eye which sees in the dark, but at that time the "eye" was not fairly open, and having then not been brought to its present rapidity of use, the early results were attained only by such unlimited repetition, and almost infinite patience was needed till what was inaccurate was eliminated.

Several hundreds at least of galvanometer readings were then taken to establish the place of *each* of the above twenty lines during the two years when they were being hunted for, and this patience so far found its reward that they have never required any material alteration since, but only additions such as the writer can now give. The part below 1.1^μ he then presented (at the Southampton meeting of the British association) as having been mapped for the first time. Mouton had two years before obtained crude indications of heat as far as 1.8^μ, and Abney had, as stated, obtained relatively complete photographs of the upper infra-red extending to about this point (1.1^μ).

The writer had already determined for the first time by the bolometer, at Allegheny and on Mount Whitney, the wave-lengths of some much remoter regions, including, in part, the region then first discovered by him and here called "the new spectrum," and was able to state that the terminal ray of the solar spectrum, whose presence had *then* been certainly felt by the bolometer, had a wave-length of about 2.8^μ, or nearly two octaves below the "great A" of Fraunhofer.

He stated in this communication of 1882 that the galvanometer then responded readily to changes of temperature in the bolometer strip, of much less than one ten-thousandth of a degree Centigrade, (as has just been said, it now responds to changes of less than one one-hundred-millionth), and he added: "Since it is one and the same solar energy, whose manifestations are called 'light' or 'heat' according to the medium which interprets them, what is 'light' to the eye is 'heat' to the bolometer, and what is seen as a dark line by the eye is felt as a cold line by the sentient instrument. Accordingly, if lines analogous to the dark 'Fraunhofer' lines exist in this invisible region, they will appear (if I may so speak) to the bolometer as cold bands, and this hair-like strip of platinum is moved along in the invisible part of the spectrum till the galvanometer indicates the all but infinitesimal change of temperature caused by its contact with such a 'cold band.' The whole work, it will be seen, is necessarily very slow; it is, in fact, a long groping in the dark and it demands extreme patience."

At that time it may be said to have been shown that these interruptions were due to the existence of something like dark lines or bands, resembling what are known as the Fraunhofer lines in the upper spectrum; but, apart from what the writer had done, no one then surmised how far this spectrum extended nor, perhaps, what these explorations really meant. They may be compared to actual journeys into this dark continent, if it may be so called, which extended so far beyond those of previous explorers that the determination of positions by the writer, corresponding somewhat to longitudes determined by the terrestrial explorer in a new country, was, by those who had not been so far but had conceived an inadequate idea of the extent of the region, treated as erroneous and impossible.

A necessary limit to the farthest infra-red was in 1880 supposed to exist near the wave-length 1^{μ}. Doctor John Draper,[1] for instance, announced in other terms that the extreme end of the invisible spectrum might, from theoretical considerations, be probably estimated at something less than the wave-length of 1^{μ}, whence it followed that the above value of 1.8^{μ} was impossible, and, still more, that of 2.8^{μ}. If, in this connection, we revert to our map, where the visible spectrum has an extent in wave-lengths of 0.36^{μ}, then, on that same scale, the length of the entire possible spectrum, visible and invisible, was fixed by Draper at the point there shown near the band $\rho\sigma\tau$. In still other words, according to him the very end of any spectrum at all would be less than 3 on a scale in which the visible spectrum was 1. Doctor Draper's authority was deservedly respected, and this citation of his remarks is made only to show the view then entertained by eminent men of science.

Now, the writer had proved by actual measurement that it extended far beyond this point, and had announced, as the result of experiment, that it extended at any rate to about three times the utmost length then assigned from theoretical reasons by Draper, founded on the then universally accepted formula of Cauchy, which was later discredited by the direct experimental evidence given of its falsity by the bolometer.

The bolometer, which is wholly independent of light as a sensation and notes it only as a manifestation of energy, first lays down the spectrum by curves of energy from which the linear spectrum is in turn derived. Two such curves taken at different times are given to show the agreement. There must now be explained, however briefly, the way in which these energy curves, which are the basis of all, have actually been produced here.

In making the map of the energy curves it should be remembered that when an invisible band or line is suspected, its presence is revealed by the change of temperature in the bolometer strips affecting the needle of the galvanometer, causing this needle to swing this way or that; let us suppose to the left if from cold and the right if from heat. The writer's first method was to have one person to note the exposure, another to note the extent of the deflection, and a third to note the

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[1] Proceedings of the American Academy, vol. xvi, p. 233, 1880.

part of the spectrum in which it occurred. For reasons into which he does not enter, this old plan was tedious in the extreme and required, as has been said, hundreds of observations to fix with appropriate accuracy the position in wave-length of one invisible line. It has been stated that only about twenty such lines had been mapped out in nearly two years of assiduous work prior to 1881, and if a thousand such lines existed, it was apparent that fifty years would be required to denote them.

The writer then devised a second apparatus to be used in connection with the bolometer. This apparatus was simple in theory, though it has taken a dozen years to make it work well in practice, but it is working at last, and with this the maps in this volume of the "Annals" and that before us have been chiefly made. It is almost entirely automatic, and as it is now used, a thousand inflections can be delineated in a single hour, much better than this could have been done in the half century of work just referred to.

Briefly, the method is this: A great rock-salt prism (for a glass one would not transmit these lower rays nor could they easily be detected in the overlapping spectra of the grating) is obtained of such purity and accuracy of figure, and so well sheltered from moisture, that its clearness and its indications compare favorably, even in the visible spectrum, with those of the most perfect prism of glass, with the additional advantage that it is permeable to the extreme infra-red rays in question. This prism rests on a large azimuth circle turned by clockwork of the extremest precision, which causes the spectrum to move slowly along, and in one minute of time, for example, to move exactly one minute of arc of its length before the strip of the bolometer, bringing this successively in contact with one invisible line and another. Since what is blackness to the eye is cold to the bolometer, the contact of the black lines chills the strip and increases the electric current. The bolometer is connected by a cable with the galvanometer, whose consequent swing to the right or the left is photographically registered on a plate which the same clockwork causes to move synchronously and uniformly up or down by exactly one centimeter of space for the corresponding minute. By this means the energy curve of an invisible region, which directly is wholly inaccessible to photography, is photographed upon the plate.

Let it be noted that whatever the relation of the movement of the spectrum to that of the plate is, (and different ones might be adopted), it is absolutely synchronous—at least to such a degree that an error in the position of one of these invisible lines can be determined, as has been stated, with the order of precision of the astronomical measurement of visible things.

The results were before them in the energy curves and the linear infra-red spectrum containing over seven hundred invisible lines. This is more than the number of visible ones in Kirchoff & Bunsen's charts. The position of each line is fixed from a mean of at least six independent determinations with the accuracy stated above.

The reader will perhaps gather a clearer idea of this action if he imagines the map before him hung up at right angles to its actual position, so that a rise in the energy curve given would be seen to correspond to a deflection to the right, and a fall, to one to the left: for in this way the deflections were written down on the moving photographic plate from which this print has been made. The writer was now speaking of the refinements of the most recent practice; but there was something in this retrospect of the instrument's early use which brought up a personal reminiscence which he asked the Academy to indulge him in alluding to.

This was that of one day in 1881, nearly twenty years ago, when being near the summit of Mount Whitney, in the Sierra Nevadas, at an altitude of 12,000 feet, he there, with this newly invented instrument, was working in this invisible spectrum. His previous experience had been that of most scientific men—that very few discoveries come with a surprise, and that they are usually the summation of the patient work of years.

In this case, almost the only one in his experience, he had the sensations of one who makes a discovery. He went down the spectrum, noting the evidence of invisible heat die out on the scale of the instrument until he came to the apparent end even of the invisible, beyond which the most prolonged researches of investigators up to that time had shown nothing. There he watched the indications grow fainter and fainter until they too ceased at the point where the French investigators believed they had found the very end of the end. By some happy thought he pushed the indications of this delicate instrument into the region still beyond. In the still air of this lofty region the sunbeams passed unimpeded by the mists of the lower earth, and the curve of heat, which had fallen to nothing, began to rise again. There was something there. For he found, suddenly and unexpectedly, a new spectrum of great extent, wholly unknown to science and whose presence was revealed by the new instrument, the bolometer.

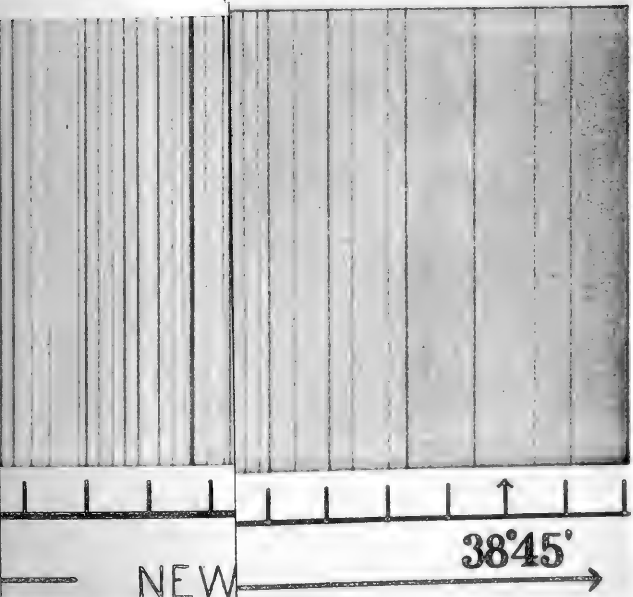
This new spectrum is given on the map, where it will be observed that while the work of the photograph (much more detailed than that of the bolometer, where it can be used at all) has been stated to extend, as far as regular mapping is concerned, to about 1.1^{μ}, that everything beyond this is due to the bolometer, except that early French investigators had found evidence of heat extending to 1.8^{μ}. Still beyond that ultima thule, this region, which he has ventured to call the "New Spectrum," extends. It will be found between wave-lengths 1.8^{μ} and 5.3^{μ} on the map.

The speaker had been much indebted to others for the perfection to which the apparatus, and especially the galvanometer, had been brought. He was under obligations, particularly to Mr. Abbot, for assistance in many ways, which he had tried to acknowledge in the volume; but before closing this most inadequate account of it, he would like to draw attention to one feature which was not represented in the spectrum map before them, although it would be found in the book.

During early years the impression had been made upon him that there were changes in the spectrum at different periods of the year. Some of these changes might be in the sun itself. The major portion of those he was immediately speaking of, he believed, were rather referable to absorptions in the earth's atmosphere.

Now these early impressions had been confirmed by the work of the observatory in recent years, and charts given in the volume would show that, (the sun being always supposed to be at about the same altitude, and its rays to traverse about the same absorbing quantity of the earth's atmosphere), the energy spectrum was distinctly different in spring, in summer, in autumn, and in winter. The lateness of the hour prevented him from enlarging on this latter profoundly interesting subject. He would only briefly point out the direction of these changes, which were not perhaps to be called conspicuous, but which seemed to be very clearly brought out as certainly existing. With regard to them he would only observe, what all would probably agree to, that while it has long been known that all life upon the earth, without exception, is maintained by the sun, it is only recently that we seem to be coming by various paths, and among them by steps such as these, to look forward to the possibility of a knowledge which has yet been hidden to us, of the way in which the sun maintains it. We were hardly beginning to see yet how this could be done, but we were beginning to see that it might later be known, and to see how the seasons, which wrote their coming upon the records of the spectrum, might in the future have their effects upon the crops prevised by means somewhat similar to those previsions made day by day by the Weather Bureau, but in ways infinitely more far-reaching, and that these might be made from the direct study of the sun.

We are yet, it is true, far from able to prophesy as to coming years of plenty and of famine, but it is hardly too much to say that recent studies of others as well as of the writer, strongly point in the direction of some such future power of prediction.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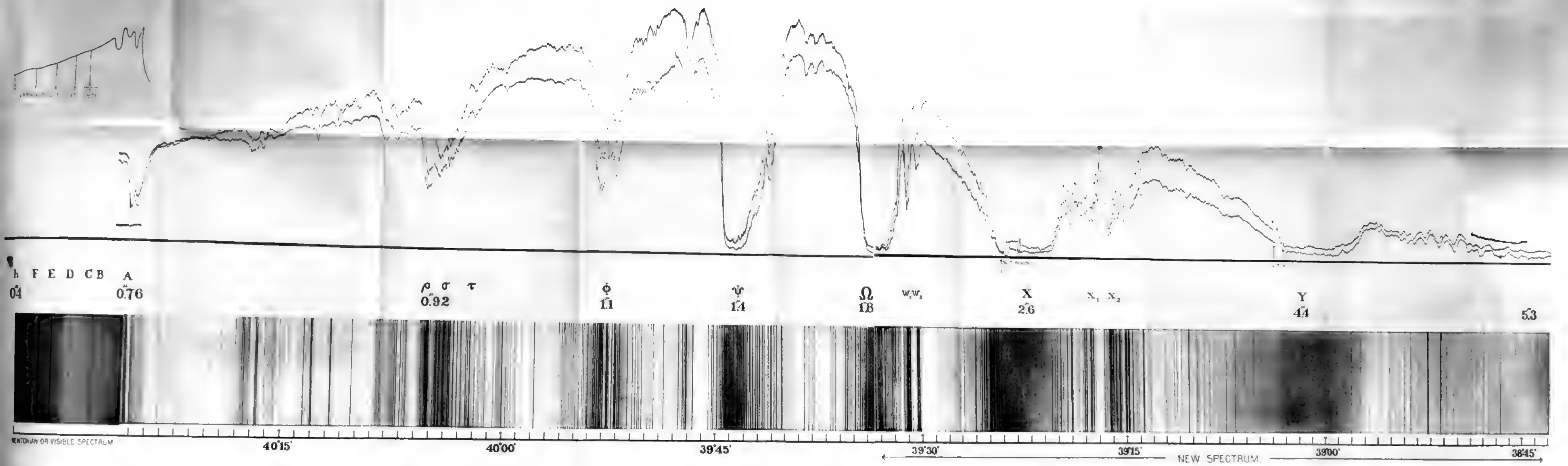

THE INFRA RED SOLAR SPECTRUM OF A 60° ROCK SALT PRISM. ENERGY CURVES AND LINES [illegible]

OBSERVATIONS OF S. P. LANGLEY WITH THE [illegible]

THE CENTURY'S GREAT MEN IN SCIENCE.[1]

By Charles S. Peirce.

How shall we determine that men are great? Who, for instance, shall we say are the great men of science? The men who have made the great and fruitful discoveries? Such discoveries in the nineteenth century have mostly been made independently by two or more persons. Darwin and Wallace simultaneously put forth the hypothesis of natural selection. Clausius, Rankine, and Sadi-Carnot, perhaps Kelvin, worked out the mechanical theory of heat. Krönig, Clausius, Joule, Herapath, Waterston, and Daniel Bernouilli independently suggested the kinetical theory of gases. I do not know how many minds besides Robert Mayer, Colding, Joule, and Helmholtz hit upon the doctrine of the conservation of energy. Faraday and Joseph Henry brought magneto-electricity to light. The pack of writers who were on the warm scent of the periodic law of the chemical elements approached two hundred when the discovery itself, a most difficult inference, was partly achieved by Lothar Meyer, wholly by Mendeléef. When great discoveries were thus in the air, shall that brain necessarily be deemed great upon which they happened earliest to condense, or the man super-eminent who, by the unmeaning rule of priority of publication, gets the credit in brief statements? No, this method of estimation, natural as it is to make success the standard of measure, will not do.

Shall we, then, by a logical analysis, draw up an abstract definition of greatness and call those men great who conform to it? If there were no dispute about the nature of greatness, this might probably prove the most convenient plan. It would be like a rule of grammar adduced to decide whether a phrase is good English or not. Nor would the circumstance that the definition could not be as explicit and determinate as a rule of grammar constitute a serious difficulty. Unfortunately, however, among the few writers who have seriously studied the question, the most extreme differences prevail as to the nature of great men. Some hold that they are fashioned of the most ordinary clay, and that only their rearing and environment, conjoined

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with fortunate opportunities, make them what they are. The heaviest weight, intellectually, among these writers maintains, on the other hand, that circumstances are as powerless to suppress the great man as they would be to subject a human being to a nation of dogs. But it was only the blundering Malvolio who got the notion that some are born great. The sentence of the astute Maria was: "Some are become great; some atcheeves greatnesse, and some have greatnesse thrust uppon em." Amid this difference of opinion any definition of greatness would be like a disputed rule of grammar. Just as a rule of grammar does not render an expression bad English, but only generalizes the fact that good writers do not use it, so, in order to establish a definition of greatness, it would be necessary to begin by ascertaining what men were and what men were not great, and that having been done the rule might as well be dispensed with. My opinion will, I fear, be set down by some intellectual men as foolishness, though it has not been lightly formed nor without long years of experimentation—that the way to judge of whether a man was great or not is to put aside all analysis, to contemplate attentively his life and works, and then to look into one's heart and estimate the impression one finds to have been made. This is the way in which one would decide whether a mountain were sublime or not. The great man is the impressive personality, and the question whether he is great is a question of impression.

The glory of the nineteenth century has been its science, and its scientific great men are those whom I mean here to consider. Their distinctive characteristic throughout the century, and more and more so in each succeeding generation, has been devotion to the pursuit of truth for truth's sake. In this century we have not heard a Franklin asking, "What signifies a philosophy which does not apply itself to some use?"—a remark that could be paralleled by utterances of Laplace, of Rumford, of Buffon, and of many another well-qualified spokesman of eighteenth-century science. It was in the early dawn of the nineteenth that Gauss (or was it Dirichlet?) gave as the reason of his passion for the Theory of Numbers that "it is a pure virgin that never has been and never can be prostituted to any practical application whatsoever." It was my inestimable privilege to have felt as a boy the warmth of the steadily burning enthusiasm of the scientific generation of Darwin, most of the leaders of which at home I knew intimately, and some very well in almost every country of Europe. I particularize that generation without having any reason to suspect that that flame has since burned dimmer or less purely, but simply because if a word belonged to one's mother tongue, one may be supposed to know unerringly the meaning the teachers of one's boyhood attached to it.

The word science was one often in those men's mouths, and I am quite sure they did not mean by it "systematized knowledge," as former ages had defined it, nor anything set down in a book; but, on the contrary, a mode of life; not knowledge, but the devoted, well-considered life pursuit of knowledge; devotion to truth—not "devotion to truth as one sees it," for that is no devotion to truth at all, but only to party—no, far from that, devotion to the truth that the man is not yet able to see but is striving to obtain. The word was thus, from the etymological point of view, already a misnomer. And so it remains with the scientists of to-day. What they meant and still mean by "science" ought, etymologically, to be called philosophy. But during the nineteenth century it was only a metaphysical professor of a now obsolescent type, as I hope, who could sit in his academic chair, puffed up with his "systematized knowledge"—no true philosopher, but a mere philodoxer. For a snap shot at the nineteenth century man of science one may take Sir Humphrey Davy, willing, as early as 1818, seriously to investigate the liquefaction of the blood of St. Januarius; or John Tyndall, with scientific ingenuousness proposing that prayer test to which no clerical Elijah has yet been found with the faith and good faith to respond; or William Crookes, devoting years of his magnificent powers to examining the supposed evidences of the direct action of mind upon matter in the face of the world's scorn. Contrast these instances with the refusal of Laplace and Biot in the closing years of the previous century to accept the evidence that stones fall from heaven (evidence proving that they do so daily), simply because their prepossessions were the other way. One of the geologist brothers De Luc declared that he would not believe such a thing though he saw it with his own eyes; and a scientifically given English ecclesiastic who happened to be sojourning in Siena when a shower of aerolites were dashed in broad daylight into an open square of that town, wrote home that having seen the stones he had found the testimony of eyewitnesses so unimpeachable and so trustworthy that—that he accepted the fact, you will say? by no means—that he knew not what to think! Such was the bon sens that guided the eighteenth century—a pretty phrase for ineradicable prejudice.

To this self-effacement before the grandeur of reason and truth is traceable the greatness of nineteenth-century science, most obviously in mathematics. In the minds of eighteenth-century mathematicians their science existed for the sake of its applications. Forgetfulness of this was in their eyes reprehensible, immoral. The question was, what would a given piece of mathematics do? They liked smooth-running and elegant machinery—there was economy in that; but they were not sedulous that it should have symmetry; idle admiration of its beauty they hardly approved. If it was excessively complicated and intricate, that was regarded rather as a feature to be proud of than as a blemish. Were the complete revolution that the nineteenth century wrought upon the ideal of mathematics not notorious, one could soon convince himself of it by looking over almost any modern treatise—say, Salmon on Higher Plane Curves. That volume, for example, would be found replete with theorems hardly any of which hold good for any curves that could really exist. Realizable curves have hardly been studied at all, for the reason that they do not yield a beautiful theory, such as is now exacted. Modern mathematics is highly artistic. A simple theme is chosen, some conception pretty and charming in itself. Then it is shown that by simply holding this idea up to one's eye and looking through it a whole forest that before seemed a thick and tangled jungle of brushes and briers is seen to be in reality an orderly garden. The word generalization really can not be fully understood without studying modern mathematics; nor can the beauty of generalization be in any other way so well appreciated. There is here no need of throwing out "extreme cases." Far from that, it is precisely in the extreme cases that the power and beauty of the magic eyeglass is most apparent and most marvellous. Let me take back the word "magic," though, for the reasonableness of it is just its crowning charm. I must not be led away from my point, to expatiate upon the reposefulness of the new mathematics, upon how it relieves us of that tiresome imp, man, and from the most importunate and unsatisfactory of the race, one's self. Suffice it to say that it is so reasonable, so simple, so easy to read, when the right view has once been attained, that the student may easily forget what arduous labors were expended in constructing the first convenient pathway to that lofty summit, that mastery over intricacies, far beyond that of the eighteenth-century master. "It must not be supposed," said C. G. J. Jacobi, one of the simplifying pioneers, "that it is to a gift of nature that I owe such mathematical power as I possess. No; it has come by hard work, hard work. Not mere industry, but brain-splitting thinking—hard work; hard work that has often endangered my health." Such reflections enable us to perceive that if modern mathematics is great, so also were the men who made it great.

The science next in abstractness after mathematics is logic. The contributions of the eighteenth century to this subject were enormous. In pure logic the doctrine of chances, which has been the logical guide of the exact sciences and is now illuminating the pathway of the theory of evolution, and is destined to still higher uses, received at the hands of Jacob Bernouilli and of Laplace developments of the first importance. In the theory of cognition Berkeley and Kant laid solid foundations; their personal greatness is incontestable. This is hardly true of Hume. In the nineteenth century Boole created a method of miraculous fruitfulness, which aided in the development of the logic of relatives, and threw great light on the doctrine of probability, and thereby upon the theory and rules of inductive reasoning. De Morgan added an entirely new kind of syllogism, and brought the logic of relatives into existence, which revolutionizes general conceptions of reasoning. The works of Comte, Whewell, J. S. Mill, Jevons, and others upon the philosophy of inductive science were less successful or fruitful. In the more metaphysical part of logic the philosophy of Hegel, though it can not be accepted on the whole, was the work of a great man. In metaphysics and general cosmology the attitude of the century has been expectant. Herbert Spencer has been proclaimed as a sort of scientific Messiah by a group of followers more ardent than philosophic, which does not seem to be gathering strength.

At the head of the physical sciences stands nomological physics. Dr. Thomas Young was here the earliest great man of the century, whose intellect illuminated every corner to which it was directed, taking the first difficult steps in the decipherment of the hieroglyphics, originating the doctrine of color-mixtures, propounding the correct theory of light, and illuminative everywhere. It gives a realizing sense of the century's progress that this great man in its early years should have opined that experimentation in general had then been pushed about far enough. On that occasion it was not his usual logic, but the eighteenth-century watchword "le bon sens," that was his guide, with the sort of result it is continually turning out when used beyond its proper sphere of every-day practical affairs. The advance of years, with their experience, has led physicists to expend more and vastly more effort upon extreme precision, against every protest of good sense. What has come of it? Marconi's wireless telegraphy, for one thing. For it was the precision with which the velocity of light on the one hand and the ratio of statical and dynamical constants of electricity on the other had been determined that proved to Maxwell that the vibrating medium of light was the substance of electricity, a theory that his great follower, Hertz, applied to making giant light waves less affected by obstructions than even those of sound. I dare say, sapient "good sense" pooh-poohs those wonderful new substances, helium and the rest, that seem the connecting link between ordinary matter and the ether. So it would be useless to point out that their discovery was entirely due to Lord Rayleigh's fastidiousness in the determination of the density of nitrogen. But it has to be noted as a characteristic of the great physicists of the nineteenth century that their reverence for every feature of the phenomenon, however minute, has been in thorough disaccord with the older "good sense." The greatest advances in physics during the century were made by several men at once. Certain ideas would come somehow to be in the air; and by the time they had crystalized for a student here and there, he would hesitate to announce as original conceptions what he had reason to suppose many men shared, while he knew that the larger body would not be yet ready to accept them. Under those circumstances priority of publication can signify nothing except haste.

Of all men of the century Faraday had the greatest power of drawing ideas straight out of his experiments and making his physical apparatus do his thinking, so that experimentation and inference were not two proceedings, but one. To understand what this means, read his "Researches on Electricity." His genius was thus higher than that of Helmholtz, who fitted a phenomenon with an appropriate conception out of his store, as one might fit a bottle with a stopper. The most wonderful capacity for "catching on" to the ideas of nature when these were of a complicated kind was shown by Mendeléef in making out the periodic law of the chemical elements, as one might make out the meaning of a pantomime, from data so fragmentary, and in some cases erroneous, that the interpretation involved the correction of sundry facts, corrections since confirmed, as well as the prediction of the very peculiar properties of the unknown gallium, scandium, and germanium, which were soon afterwards actually met with. Minute examination of all his utterances convinces one that Mendeléef's mental processes in this unparalleled induction were largely subconscious and, as such, indicate an absorption of the man's whole being in his devotion to the reason in facts.

A great naturalist, as well as I can make out, is a man whose capacious skull allows of his being on the alert to a hundred different things at once, this same alertness being connected with a power of seeing the relations between different complicated sets of phenomena when they are presented in their entirety. The eighteenth century had its Linnæus, whose greatness even I can detect as I turn over his pages; its Huber, discovering through others' eyes what others could not discern with their own; its Goethe, its Haller, its Hunter, and mixed with practical greatness, its Pinel and its Jenner. Then, there was Lavater, who showed how pure æsthetic estimation might be turned to the discovery of truth—a man depreciated because logicians and philodoxers can so much more easily detect his weakness than discern his strength. The nineteenth century, with its great thinker, Darwin; its Pasteur (great in chemistry as well as in biology, a man who impressed me personally, and impresses me in his works, as much as any but two or three of the century); its Lamaroll, Weissmann, Cuvier, Agassiz, von Baer, Bichat, Johannes Müller, Robert Brown, and I know not whom besides, has certainly garnered a magnificent harvest of great men from this field.

Those sciences which study individual objects and seek to explain them upon physical principles—astronomy, geology, etc., corresponding to history and biography on the psychical side—demand the greatest assemblage of different powers. Those who pursue them have first to be mathematicians, physicists, chemists, naturalists, all at once, and, after that, astronomers or geologists in addition. It is almost beyond human power. In the eighteenth century A. G. Werner broke ground in geology. William Herschel, Kant, and Laplace did great things in astronomy. In the nineteenth century geology was first really made a science, and among its great men one recalls at once Lyell, Agassiz, Kelvin. This country has become its home. In astronomy, too, this country has been eminent, especially in the new astronomy which has afforded the needed scope for greatness, instead of the narrow rut that Bessel and Argelander had left behind them. Thus it happens that we have a magnificent group of great astronomers living among us to-day. We stand too close to them to take in their true proportions. But it is certain that the names of Chandler, Langley, Newcomb, Pickering, and several others are indelibly inscribed upon the heavens. In England it is only this year that Sir Norman Lockyer has brought the extraordinary research to which his life has been devoted to completion, so far as such work can be said to be capable of completion. It is an attribute of its greatness that it is endless.

When we compare all the men I have glanced at, with a view to eliciting a common trait somewhat distinctive of the nineteenth century, we can not but see that science has been animated by a new spirit, till the very word has become a misnomer. It is the man of science, eager to have his every opinion regenerated, his every idea rationalized, by drinking at the fountain of fact, and devoting all the energies of his life to the cult of truth, not as he understands it, but as he does not yet understand it, that ought properly to be called a philosopher. To an earlier age knowledge was power, merely that and nothing more; to us it is life and the summum bonum. Emancipation from the bonds of self, of one's own prepossessions, importunately sought at the hands of that rational power before which all must ultimately bow—this is the characteristic that distinguishes all the great figures of the nineteenth-century science from those of former periods.

THE LESSON OF THE LIFE OF HUXLEY.

By William Keith Brooks,

Professor of Zoology in the Johns Hopkins University.

> Science seems to me to teach in the highest and strongest manner the great truth which is embodied in the Christian conception of entire surrender to the will of God. Sit down before fact as a little child, be prepared to give up every preconceived notion, follow humbly wherever and to whatsoever abysses nature leads, or you shall learn nothing. I have only begun to learn content and peace of mind since I have resolved, at all risks, to do this.—Life and Letters of Thomas Henry Huxley, I, page 235.

No one can study Huxley's works without discovering that his whole life was devoted to a definite and clearly perceived purpose, and he has himself told us what that purpose was.

> If I may speak of the objects I have had more or less definitely in view, they are briefly these: To promote the increase of natural knowledge, and to forward the application of scientific methods to all the problems of life, to the best of my ability, in the conviction, which has grown with my growth, and strengthened with my strength, that there is no alleviation for the sufferings of mankind except veracity of thought and action, and the resolute facing of the world as it is when the garment of make-believe with which pious hands have hidden its uglier features has been stripped off.

He tells us it is with this intent that he has subordinated ambition for scientific fame to the diffusion among men of that enthusiasm for truth, that fanaticism of veracity, which is a greater possession than much learning, a nobler gift than the power of increasing knowledge.

The changes which science has brought about in our conceptions of nature and our relation to the world around us have never been more clearly or more eloquently set forth than in the address "On the advisableness of improving natural knowledge," to which Huxley has given the foremost place in his volumes of collected essays. If, in order to make clear what was the task to which his life was devoted, I venture to give an abstract of this gem of English literature, I do this in the hope that new readers may be led to find delight in the beautiful original, which is worthy to be read in schools as an illustration of the union of scientific knowledge with literary genius.

This time two hundred years ago, he tells us in 1866, those of our forefathers who inhabited this great and ancient city took breath between the shocks of two fearful calamities; one not quite past, although its fury had abated; the other to come.

Within a very few yards of the spot on which the address was delivered, so tradition runs, that painful and deadly malady, the plague, appeared and smote the people of England with a violence unknown before, stalking through the narrow streets of old London, and changing their busy hum into a silence broken only by the wailing of the mourners for 50,000 dead.

About this time, in 1666, the death rate had sunk to nearly its normal amount, and the people began to toil at the accustomed round of duty or of pleasure, and the stream of the city life bid fair to flow back into its old bed, with renewed and uninterrupted vigor.

The newly kindled hope was deceitful. The great plague, indeed, returned no more; but what it had done for Londoners, the great fire, which broke out in the autumn of 1666, did for London; and in September of that year a heap of ashes and the indestructible energy of the people were all that remained of the glory of five-sixths of the city within the walls.

Our forefathers had their own way of accounting for each of these calamities. They submitted to the plague in humility and in penitence, for they believed it to be the judgment of God. But toward the fire they were furiously indignant, interpreting it as the effect of the malice of man—as the work of the Republicans or of the Papists, according as their prepossessions ran in favor of loyalty or of Puritanism.

It would have fared but ill, says Huxley, with one who, standing where I now stand, should have broached to our ancestors the doctrine which I now propound to you—that all their hypotheses were alike wrong; that the one thing needful was that they should second the efforts of an insignificant corporation "for improving natural knowledge," the establishment of which might have loomed larger than the plague and outshone the glare of the fire to him who had the gift of distinguishing between prominent events and important events.

If the noble first president of the Royal Society could revisit the upper air he would find himself in the midst of a material civilization more different from that of his day than that of the seventeenth was from that of the first century.

And if his native sagacity had not deserted his ghost he would need no long reflection to discover that all these great ships, these railways, these telegraphs, these factories, these printing presses, without which the whole fabric of modern society would collapse into a mass of stagnant and starving pauperism—that all these pillars of our State are but the ripples and the bubbles upon the surface of that great spiritual stream, the springs of which only he and his fellows were privileged to see, and seeing, to recognize as that which it behooved them, above all things, to keep pure and undefiled.

It may not be too great a flight of the imagination to conceive him not forgetful of the great troubles of his own day, and anxious to know how often London had been burned down and how often the plague had carried off its thousands. He would have to learn that natural knowledge has furnished us with dozens of engines for throwing water upon fires, and that except for the progress of natural knowledge we should not be able to make even the tools by which these machines are constructed. And it would be necessary to add that although severe fires sometimes occur and inflict great damage, the loss is very generally compensated by societies the operations of which have been rendered possible only by the progress of natural knowledge.

But the plague! His observations would not lead him to think that we of the nineteenth century are purer of life or more fervent in religious faith than the generation which could produce a Boyle, an Evelyn, and a Milton. And it would be our duty to explain once more, and this time not without shame, that we have no reason to believe it is the improvement of our faith, nor that of our morals, which keeps the plague from us; but again, that it is the improvement of our natural knowledge. We, in later times, have learned somewhat of nature and partly obey her. Because of this partial improvement of our natural knowledge and of that fractional obedience we have no plague. Because that knowledge is very imperfect, and that obedience yet incomplete, typhoid is our companion and cholera our visitor. But it is not presumptuous to express the belief that when our knowledge is more complete, and our obedience the expression of our knowledge, London will count her centuries of freedom from typhoid and cholera as she now gratefully reckons up her two hundred years of ignorance of that plague which swooped upon her thrice in the first half of the seventeenth century.

It is very certain that for every victim slain by the plague hundreds of mankind exist and find a fair share of happiness in the world by the aid of the spinning jenny. And the great fire, at its worst, could not have burned the supply of coal, the daily working of which, in the bowels of the earth, made possible by the steam pump, gives rise to an amount of wealth to which the millions lost in old London are but as an old song.

But spinning jenny and steam pump are after all but toys, possessing an accidental value, and natural knowledge creates multitudes of more subtle contrivances, the praise of which does not happen to be sung because they are not directly convertible into wealth.

If natural knowledge were only a sort of fairy godmother, ready to furnish her pets with shoes of swiftness, swords of sharpness, and omnipotent Aladdin's lamps, so that they may have telegraphs to Saturn, and see the other side of the moon, and thank God they are better than their benighted ancestors, I, for one, says Huxley, should not greatly care to toil in the service of natural knowledge. I think I would just as soon be quietly chipping my own flint ax, after the manner of my forefathers a few thousand years back, says he, as be troubled with the endless malady of thought which now infests us all for such a reward. But I venture to say that such views are contrary alike to reason and to fact.

The improvement of natural knowledge, whatever direction it has taken, and however low the aims of those who have commenced it, has not only conferred practical benefits on men, but in so doing has effected a revolution in their conceptions of the universe and of themselves, and has profoundly modified their modes of thinking and their views of right and wrong. Natural knowledge, seeking to satisfy natural wants, has found the ideas which can alone still spiritual cravings—in desiring to ascertain the laws of comfort has been driven to discover those of conduct and to lay the foundations of a new morality.

He who is endowed with the spirit of modern science absolutely refuses to acknowledge authority as such. For him, scepticism is the highest of duties; blind faith, the one unpardonable sin. And it can not be otherwise, for every great advance in natural knowledge has involved the absolute rejection of authority, the cherishing of the keenest scepticism, the annihilation of the spirit of blind faith, and the most ardent votary of science holds his firmest convictions not because the men he most venerates hold them, not because their verity is testified by portents and wonders, but because his experience teaches him that whenever he chooses to test these convictions by appealing to experiment and observation he may expect them to be confirmed. The man of science has learned to believe in justification not by faith, but by verification.

If these ideas are destined to be more and more firmly established as the world grows older, if the scientific spirit be fated to extend itself into all departments of human thought and to become coextensive with the range of human knowledge, if as our race approaches maturity it discovers that there is but one kind of knowledge and but one method of acquiring it, then we, who are still children, may justly feel it our highest duty to recognize the advisableness of improving natural knowledge, and so to aid ourselves and our successors in our course toward the noble goal which lies before mankind.

It is because of this conviction that Huxley assures us truth is better than much profit; because of it that he turned aside from his scientific researches in order to do his part in keeping pure and undefiled the springs of natural knowledge.

No one—Huxley least of all—would dream of attributing the "New Reformation" to any one man, and he speaks of himself as a "full private who has seen a good deal of service in the ranks" of the army ranged round the banner of science; but the object to which his life was devoted—the diffusion among men of the scientific spirit of "organized common sense"—has made notable progress during his lifetime, and in this assurance he tells us at its end that he "shall be content to be remembered, or even not remembered," as one among the many who brought it about.

The opening paragraph of his book on "Hume" may be taken as a statement of the motive of all Huxley's works. "Kant has said that the business of philosophy is to answer three questions: What can I know? What ought I to do? and For what may I hope? But it is pretty plain that these three resolve themselves in the long run into the first; for rational expectation and moral action are alike based upon belief, and a belief is void of justification unless its subject-matter lies within the boundaries of positive knowledge, and unless its evidence satisfies the conditions of credibility. Fundamentally, then, philsophy is the answer to the question What can I know?"

Huxley is not drawn into this province by the fierce joy of controversy, nor by any desire to join those who flit forever over dusky meadows green with asphodel in vain search for some reality which is not within the easy reach of all of us. His motive is the most practical and serious one we know—"to learn what is true in order to do what is right." This, he tells us, "is the summing up of the whole duty of man, for all who are not able to satisfy their mental hunger with the east wind of authority."

The conclusion of the whole matter is that there is but one kind of knowledge, and only one way to acquire it. This is the melody which runs through all his works; now loud and clear, now hidden by the minor interest of a scientific topic, or by the heat of controversy, or by the charm of eloquence and literary genius; but always present, and easy, for one who listens, to detect.

It is because scientific education helps us to acquire the method of using our reason rightly in the search for truth that he gave so much of his time and strength to the problems of education. It is because the improvement of natural knowledge is conclusive proof of the value of this method that he devoted his life to the popularization of science. It is because his right to use this method—the right which is also the first and highest of duties—was disputed, that he entered the stormy waters of controversy.

After the publication of the Origin of Species, Huxley became the most alert and fearless and skilful of its advocates—interested in it as a great contribution to zoology, and interested in it also, it seems to me, as a great contribution to our views of natural knowledge and our way to acquire it.

The a priori philosophers tell us we may arrive at truth by deducing it from propositions which are incapable of proof, because they are self-evident to the normal man; and they talk about the normal man as if he were a prominent citizen, the personal acquaintance of all who have any claim to be considered men of intellect, and a familiar face even to the common herd.

The publication of the Origin of Species has made it clear to the man of science that he knows no such person; that all men are individual men, and the normal man a fictitious character, a statistical average, and a mere abstraction, which does not exist in nature outside the minds of the a priori philosophers.

Nothing can be deduced from self-evident propositions by one to whom they are not self-evident, and as natural selection has come to be better understood it has made it less and less possible for the man who puts his faith in scientific methods of discovering truth, and is accustomed to have that faith justified by daily experience, to be consciously false to his principles in any matter.

To what nobler end could life be devoted than the attempt to show us how we may "learn to distinguish truth from falsehood, in order that we may be sure about our actions, and walk surefootedly in this life?" No memorial to Huxley could be more appropriate than the speedy establishment of that "intellectual liberty which is not intellectual license" on a basis so firm that the struggle to obtain it shall become a forgotten antiquity. If, as the end of his lifelong labor, intellectual freedom is established on a basis so firm that we are no longer willing to accept either authority or deduction from so-called self-evident truths as a substitute for discovery and verification, this is his best monument, even if the man should quickly be forgotten in the accomplishment of his ends, and even if he was sometimes unsuccessful in his attempts to walk by verification.

In 1868 he tells us that it is necessary to be possessed of only two beliefs in order that we may successfully perform our plain duty and make the little corner we can influence a little less ignorant and a little less miserable than we found it. The first of these beliefs, he tells us, is that the order of nature is discoverable by our faculties to an extent which is practically unlimited; the second, that our volition counts for something as a condition of the course of events. Each of these beliefs may be verified, he assures us, as often as we like to try; and common folks, no doubt, agree with him.

The progress of science, especially the progress of biological science, during the next twenty-five years, convinced Huxley, as it has convinced all thoughtful men, that we ourselves may prove to be part and parcel of that order of nature which, in unbroken continuity, composes the sum of all that is, and has been, and shall be, and this seems to him to show that our volition has no more to do with our conduct than the whistle of the locomotive engine has to do with the movement of the train; because he believes that proof that we never do anything which exhaustive knowledge of our bodily machinery might not lead one to expect would show that our conduct is "predestined" and inevitable and necessary. So, he asks us, in 1892, to change his words, and in place of the familiar conviction, which may be verified as often as we like to try, that our volition counts, read that it is not volition but the physical state of which volition is the expression which counts for something as a condition of the course of events—counting, I take it, as a rock may be expected to count as a condition of the course of the stream.

I fail to see why anyone should object to this amendment, considering it in itself, even if one see reason to ask whether it can be accepted as a substitute for the original statement. The assertion that the physical state of which volition is the sign does count as a condition of the course of events might no doubt be verified experimentally as often as one has the opportunity, for it may be that it is included in the declaration that the order of nature is discoverable by our faculties. What I do fail to discover is any antagonism between it and the original statement that our volition counts; and Huxley is unable to abide firmly and consistently by the declaration that it does not count. In 1894, only a short time before his death, he tells us that, if our conviction that there lies within us a fund of energy operating intelligently, and so far akin to that which pervades the universe that it is competent to influence and modify the cosmic process, is logically absurd, because our conduct is part and parcel of the cosmic process, he is sorry for logic, because the facts are so.

Huxley reminds us, and does well to remind us, that logical consequences are the beacon of wise men and the bugbear of fools, and while deductive philosophy may be expected to land its disciples in contradictions which no mere human wisdom can reconcile, it is a hard thing for one who tries to walk by verification to rest willingly in inconsistency.

Our well-founded conviction that there is no interference with nature, no interruption in the cosmic process, is a conviction that nature is orderly, but not that it is inevitable or predetermined or necessary, for order is a matter of fact and not an agent or a cause of things.

Huxley declares that all things are working out their "predestined" courses of evolution, but he also reminds us that evolution is not an explanation of the cosmic process, but merely a generalized statement of the methods and results of that process. Is it not clear that no statement can predestine anything, and that no amount of knowledge of a process and no amount of discovery as to what is going on can tell us who or what is carrying it on, or whether the activity of which the cosmic process is the expression is predestined or spontaneous? Processes, evolutionary or otherwise, are matters of fact. There is nothing of power or agency included in the notion of a process.

"The tenacity of the wonderful fallacy that the laws of nature are agents, instead of being, as they really are, a mere record of experience, upon which we base our interpretation of that which does happen and our anticipation of what we expect to happen, is a remarkable psychological fact," says Huxley. "If it should be worth anybody's while to hunt for examples of such misuse of language on my own part," says he, "I am not at all sure he might not succeed. If I am guilty I do penance beforehand, and I only hope I may deter others from committing the like fault."

Huxley believes that proof that our conduct, or anything else, is part and parcel of the cosmic process, and neither more nor less than one might have expected if he had known all about primitive nebulosity, would show that our volition is only "so called," and that it is the empty and meaningless accompaniment of our bodily activity.

If it is misuse of language which leads him to this conclusion—if it does not follow from the premises—it is surely worth while to point this out, not in any spirit of criticism, but solely that others may be deterred from committing the like fault.

"The necessity of any action, either of matter or of mind," says Hume, "is not, properly speaking, a quality of the agent, but in any thinking and intelligent being who may consider the action." Hume regards this obvious truth as evidence that our feeling of freedom in willing and doing is nothing more than a singular effect of custom; but may it not rather be the notion of necessity which is a singular effect of custom? If necessity is not a quality of the agent, but of the spectator, may it not be that the quality of freedom in willing and doing—if there be such freedom—is not, properly speaking, in any spectator who may consider the action, but in the free and intelligent agent?

"I take it for demonstrable," says Huxley, "that it is utterly impossible to prove that anything whatever may not be the effect of a material and necessary cause, and that human logic is equally incompetent to prove that any act is really spontaneous." But we must not forget that he is sorry for logic if there is any antagonism between this opinion and belief in our ability "to influence and modify the cosmic process." If the opinion is well warranted, as it seems to me to be, may it not be valid only because logic never does tell us any matter of fact? May it not be because it is utterly impossible to prove by logic that anything whatever is the effect of a necessary cause. that it is also impossible thus to prove that any event is not the effect of that sort of cause? If human logic is utterly incompetent to prove that all acts, or any acts, are or are not really spontaneous, may it not be that some acts are really so in the most literal meaning of the word? And if any of my acts are really spontaneous, is not my responsibility for them complete?

If, for all we know, or can expect to know, our moral responsibility may be complete, is not this all one for all practical and intellectual and moral ends, as if it were known to be complete? If wise and prudent, must not he who does not know whether his liability is limited or unlimited act as if it were unlimited? Is it not practically unlimited if he knows no limit, and may it not be actually so?

May not the eloquent words in which Huxley teaches the advisableness of improving natural knowledge be more true to nature than the ecclesiastical dogma that there is only vanity and vexation of spirit in our attempts to seek and to search out by wisdom concerning the things that are done under the sun; because our conduct, being part and parcel of the cosmic process, can be nothing more than the empty and meaningless accompaniment of the predestined activity of our bodily machinery?

Like all strong men of intellect, oppressed by the burden of that endless malady of thought which infests us, Huxley devoted the best of his powers to a search for the meaning of that natural world which we find so full of delight and entertainment and instruction, and also so full of pain and sorrow and evil. The problem of ethics was never far from his thoughts, and it is, no doubt, with this in mind that he warns us it is better to think wrongly than to think confusedly, because he who is obscure can come to no stable conclusion, while he who is wrong may, if his mind be clear, some day run against a fact which may set him right.

No one who is perplexed by the awful majesty of nature, and by the mystery of our own relation to the world around us, can fail to find profit in Huxley's reflections, for they are always fearless and honest and clear, even if they may be hard to reconcile with one another.

When, in his early manhood, death first invades his home and takes his first-born little son, he tells us, in a letter to a sympathetic friend: "The more I know intimately of the lives of other men (to say nothing of my own) the more obvious to me is it that the wicked does not flourish nor is the righteous punished. But for this to be clear we must bear in mind what almost all forget, that the rewards of life are contingent upon obedience to the whole law—physical as well as moral—and that moral obedience will not atone for physical sin, or vice versa."

In his latest public utterance in his old age, he tells us: "If there is a generalization from the facts of human life which has the assent of all thoughtful men in every age and country, it is that the violator of ethical rules constantly escapes the punishment which he deserves; that the wicked flourishes like a green bay tree; that the sins of the fathers are visited upon the children; that in the realm of nature ignorance is punished just as severely as willful wrong; that thousands upon thousands of innocent beings suffer for the crime or the unintentional trespass of one."

These two efforts to find meaning in the "sum of the customs of matter" can not both be entirely right, although both may be partially right. We must also remember that one may find serious flaws in an attempt to answer the riddle of existence, even if he have no answer of his own. Of Huxley's two utterances upon the ethical problem, the latest seems to me to present, to the inquirer who approaches the problem from the standpoint of modern biological science, certain grave difficulties from which the first is free.

If, reflecting upon some partial view of our experience, we regard it as a whole, forgetting that it is a part and not the whole, the results of our reflections may seem to be the obvious conclusion of sound reasoning, when they are no better than illustrations of the threadbare fallacy of the undistributed middle. Our minds are so constituted that a path which our thoughts have once followed becomes easier with each new venture, while it grows harder at the same time for us to consider what lies outside the borders of this path. No rational being, whose mind is such as we find ours to be, can treat a part as a complete and independent subject for reflection without danger of forgetting that it is not the whole but only a part.

"When the ancient sage looked the world, and especially human life, in the face," says Huxley, "he found it as hard as we do to bring the course of evolution into harmony with even the elementary requirements of the ethical ideal of the just and the good."

Can we seek for meaning in any natural world except the one we know, and are not the things we know our own knowledge? May not the ancient sage, in his efforts to contemplate as a spectator an experience which would not be at all if it were not his experience, have forgotten that it is only through his own eyes that he can look the world in the face? If I am to find any ethical lesson in nature, must I not ask whether the universe of which I am a part teaches me any moral lesson? Can I, with meaning in my words, ask whether it would teach a moral lesson to an unconcerned spectator?

"Brought before the tribunal of ethics, the cosmos might well seem to stand condemned," says Huxley. "The conscience of man revolted against the moral indifference of nature, and the microcosmic atom should have found the macrocosm guilty. But few have ventured to record that verdict." Is not failure to record a verdict according to the evidence to be regarded as doubt whether all the pertinent evidence has been presented? May not the reservation of its verdict by the microcosm be the expression of an unformulated conviction that the macrocosm would not be what it is if the microcosmic atom were not questioning it—a conviction that the distinction between the atom which considers its verdict and the natural world which awaits sentence is not a distinction which we find in nature, but one that we make by abstraction and generalization, considering a part as if it were the whole, and then forgetting that it is only a part and not the whole?

Is the attempt to find out whether nature teaches a moral lesson anything more or less than the question whether I am a reasonable and responsible being, able to act wisely or foolishly, and to do right and wrong?

Huxley tells us the perplexities of ethics spring from the conflict between man as a product of the cosmic process and man as a member of organized society. He says that while the self-assertive ape and tiger promptings of the natural man, which the ethical man brands by the name of sins, are the products of the survival of the fittest, life as a member of an artificially organized polity demands self-restraint instead of self-assertion, and is, in so far, antagonistic to natural selection.

One may well hesitate to assert that the greatest of all the advocates of Darwin's work has, in any degree, failed to understand it. Yet a moment's thought seems to be all that is needed to discover that the success which survives the struggle for existence is success in rearing progeny, and not the welfare of the individual. It is because all my ancestors in my long natural history did, on the whole, act in such a way as to promote my interest rather than their own, whenever there was any incompatibility between the two, that I am in existence. He who perceives that the ferocity of the tiger and the salacity of the ape are as altruistic in origin as the industry of the bee and the mother's love for her child, can no longer wonder if something in his own nature impels him to acts which are not to his personal liking or advantage; for the ethical nature of civilized man is nothing more than one might have expected from his natural history. It is no more antagonistic to the cosmic process than the fall of a stone.

It is not as an independent whole, but as part of the universe, that the stone illustrates the law of gravitation. If one were to consider it a complete and unconditioned being, and then hunt within it for a gravitative principle, would he be any more absurd than the ancient sage who forgets that it is through his own eyes that he attempts to look nature in the face and find out its meaning?

May not man's place in nature teach to the humble-minded naturalist something about ethics that was hidden from the ancient sage?

REMINISCENCES OF HUXLEY.[1]

By JOHN FISKE.

The recent publication of an admirable memoir of Huxley, by his son Leonard,[2] has awakened in me old memories of some of the pleasantest scenes I have ever known. The book is written in a spirit of charming frankness, and is thickly crowded with details not one of which could well be spared. A notable feature is the copiousness of the extracts from familiar letters, in which everything is faithfully reproduced, even to the genial nonsense that abounds, or the big, big D that sometimes, though rarely, adds its pungent flavor. Huxley was above all things a man absolutely simple and natural; he never posed, was never starched, or prim, or on his good behavior; and he was nothing if not playful. A biography that brings him before us, robust and lifelike on every page, as this book does, is surely a model biography. A brief article, like the present, can not even attempt to do justice to it, but I am moved to jot down some of the reminiscences and reflections which it has awakened.

My first introduction to the fact of Huxley's existence was in February, 1861, when I was a sophomore at Harvard. The second serial number of Herbert Spencer's First Principles, which had just arrived from London, and on which I was feasting my soul, contained an interesting reference to Huxley's views concerning a "pre-geologic past of unknown duration." In the next serial number a footnote informed the reader that the phrase "persistence of force," since become so famous, was suggested by Huxley, as avoiding an objection which Spencer had raised to the current expression "conservation of force." Further references to Huxley, as also to Tyndall, in the course of the book, left me with a vague conception of the three friends as, after a certain fashion, partners in the business of scientific research and generalization.

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[1] Copyright, 1901, by Houghton, Mifflin & Co. Reprinted from the Atlantic Monthly for February, 1901, by special permission of the author and his publishers, Houghton, Mifflin & Co.

[2] Life and letters of Thomas Henry Huxley, by his son, Leonard Huxley. In two volumes. New York: D. Appleton & Co. 1900.

Some such vague conception was developed in the mind of the general public into divers droll misconceptions. Even as Spencer's famous phrase, "survival of the fittest," which he suggested as preferable to "natural selection," is by many people ascribed to Darwin, so we used to hear wrathful allusions to Huxley's Belfast Address, and similar absurdities. The climax was reached in 1876, when Huxley and his wife made a short visit to the United States. Early in that year Tyndall had married a daughter of Lord Claud Hamilton, brother of the Duke of Abercorn, and one fine morning in August we were gravely informed by the newspapers that "Huxley and his titled bride" had just arrived in New York. For our visitors, who had left at home in London seven goodly children, some of them approaching maturity, this item of news was a source of much merriment.

To return to my story: It was not long before my notion of Huxley came to be that of a very sharply defined and powerful individuality; for such he appeared in his lectures on the Origin of Species and in his Evidence as to Man's Place in Nature, both published in 1863. Not long afterwards, in reading the lay sermon on The Advisableness of Improving Natural Knowledge, I felt that here was a poetic soul whom one could not help loving. In those days I fell in with Youmans, who had come back from England bubbling and brimming over with racy anecdotes about the philosophers and men of science. Of course the Soapy Sam incident was not forgotten, and Youmans's version of it, which was purely from hearsay, could make no pretension to verbal accuracy; nevertheless, it may be worth citing. Mr. Leonard Huxley has carefully compared several versions from eye and ear witnesses, together with his father's own comments, and I do not know where one could find a more striking illustration of the difficulty of attaining absolute accuracy in writing even contemporary history.

As I heard the antedote from Youmans: It was at the meeting of the British Association at Oxford in 1860, soon after the publication of Darwin's epoch-making book, and while people in general were wagging their heads at it, that the subject came up for discussion before a fashionable and hostile audience. Samuel Wilberforce, the plausible and self-complacent Bishop of Oxford, commonly known as "Soapy Sam," launched out in a rash speech, conspicuous for its ignorant misstatements, and highly seasoned with appeals to the prejudices of the audience, upon whose lack of intelligence the speaker relied. Near him sat Huxley, already eminent as a man of science, and known to look favorably upon Darwinism, but more or less youthful withal, only five and thirty, so that the bishop anticipated sport in badgering him. At the close of his speech he suddenly turned upon Huxley and begged to be informed if the learned gentleman was really willing to be regarded as the descendant of a monkey. Eager self-confidence had blinded the bishop to the tactical blunder in thus coarsely inviting a retort. Huxley was instantly upon his feet with a speech demolishing the bishop's card house of mistakes; and at the close he observed that since a question of personal preferences had been very improperly brought into the discussion of a scientific theory he felt free to confess that if the alternatives were descent, on the one hand from a respectable monkey, or on the other from a bishop of the English Church who could stoop to such misrepresentations and sophisms as the audience had lately listened to, he should declare in favor of the monkey.

Now this was surely not what Huxley said, nor how he said it. His own account is that, at Soapy Sam's insolent taunt, he simply whispered to his neighbor, Sir Benjamin Brodie, "The Lord hath delivered him into my hands," a remark which that excellent old gentleman received with a stolid stare. Huxley sat quiet until the chairman called him up. His concluding retort seems to have been most carefully reported by John Richard Green, then a student at Oxford, in a letter to his friend, Boyd Dawkins: "I asserted—and I repeat—that a man has no reason to be ashamed of having an ape for his grandfather. If there were an ancestor whom I should feel shame in recalling, it would rather be a man—a man of restless and versatile intellect—who, not content with an equivocal success in his own sphere of activity, plunges into scientific questions with which he has no real acquaintance, only to obscure them by an aimless rhetoric, and distract the attention of his hearers from the real point at issue by eloquent digressions and skilled appeals to religious prejudice." This can hardly be accurate; no electric effect could have been wrought by so long-winded a sentiment. I agree with a writer in Macmillan's Magazine that this version is "much too Green," but it doubtless gives the purport of what Huxley probably said in half as many but far more picturesque and fitting words. I have a feeling that the electric effect is best preserved in the Youmans version, in spite of its manifest verbal inaccuracy. It is curious to read that in the ensuing buzz of excitement a lady fainted and had to be carried from the room; but the audience were in general quite alive to the bishop's blunder in manners and tactics, and, with the genuine English love of fair play, they loudly applauded Huxley. From that time forth it was recognized that he was not the sort of man to be browbeaten. As for Bishop Wilberforce, he carried with him from the affray no bitterness, but was always afterwards most courteous to his castigator.

When Huxley had his scrimmage with Congreve, in 1869, over the scientific aspects of positivism, I was giving lectures to post-graduate classes at Harvard on the positive philosophy. I never had any liking for Comte or his ideas, but entertained an absurd notion that the epithet "positive" was a proper and convenient one to apply to scientific methods and scientific philosophy in general. In the course of the discussion I attacked sundry statements of Huxley with quite unnecessary warmth, for such is the superfluous belligerency of youth. The World reported my lectures in full, insomuch that each one filled six or seven columns, and the editor, Manton Marble, sent copies regularly to Huxley and others. Four years afterwards I went to London to spend some time there in finishing Cosmic Philosophy and getting it through the press. I had corresponded with Spencer for several years, and soon after my arrival he gave one of his exquisite little dinners at his own lodgings. Spencer's omniscience extended to the kitchen, and as composer of a menu neither Carême nor Francatelli could have surpassed him. The other guests were Huxley, Tyndall, Lewes, and Hughlings Jackson. Huxley took but little notice of me, and I fancied that something in those lectures must have offended him. But two or three weeks later Spencer took me to the dinner of the *x* Club, all the members of which were present except Lubbock. When the coffee was served Huxley brought his chair around to my side and talked with me the rest of the evening. My impression was that he was the cosiest man I had ever met. He ended by inviting me to his house for the next Sunday at 6, for what he called "tall tea."

This was the introduction to a series of experiences so delightful that, if one could only repeat them, the living over again all the bad quarters of an hour in one's lifetime would not be too high a price to pay. I was already at home in several London households, but nowhere was anything so sweet as the cordial welcome in that cosy drawing-room on Marlborough Place, where the great naturalist became simply "Pater" (pronounced Patter), to be pulled about and tousled and kissed by those lovely children. Nor could anything so warm the heart of an exile (if so melancholy a term can properly be applied to anybody sojourning in beloved London) as to have the little 7-year-old miss climb into one's lap and ask for fairy tales, whereof I luckily had an ample repertoire. Nothing could be found more truly hospitable than the long dinner table, where our beaming host used to explain, "Because this is called a tea is no reason why a man shouldn't pledge his friend in a stoup of Rhenish, or even in a noggin of Glenlivet, if he has a mind to." At the end of our first evening I was told that a plate would be set for me every Sunday, and I must never fail to come. After two or three Sundays, however, I began to feel afraid of presuming too much upon the cordiality of these new friends, and so, by a superhuman effort of self-control, and at the cost of unspeakable wretchedness, I stayed away. For this truancy I was promptly called to account, a shamefast confession was extorted, and penalties, vague but dire, were denounced in case of a second offense; so I never missed another Sunday evening till the time came for leaving London.

Part of the evening used to be spent in the little overcrowded library before a blazing fire, while we discussed all manner of themes scientific or poetical, practical or philosophical, religious or æsthetic. Huxley, like a true epicure, smoked the sweet little briarwood pipe, but he seemed to take especial satisfaction in seeing me smoke very large full-flavored Havanas from a box which some Yankee admirer had sent him. Whatever subject came uppermost in our talk, I was always impressed with the fullness and accuracy of his information and the keenness of his judgments; but that is, of course, what any appreciative reader can gather from his writings. Unlike Spencer, he was an omniverous reader. Of historical and literary knowledge, such as one usually gets from books, Spencer had a great deal, and of an accurate and well-digested sort. He had some incomprehensible way of absorbing it through the pores of his skin—at least, he never seemed to read books. Huxley, on the other hand, seemed to read everything worth reading history, politics, metaphysics, poetry, novels, even books of science; for perhaps it may not be superfluous to point out to the general world of readers that no great man of science owes his scientific knowledge to books. Huxley's colossal knowledge of the animal kingdom was not based upon the study of Cuvier, Baer, and other predecessors, but upon direct personal examination of thousands of organisms, living and extinct. He cherished a wholesome contempt for mere bookishness in matters of science, and carried on war to the knife against the stupid methods of education in vogue forty years ago, when students were expected to learn something of chemistry or palæontology by reading about black oxide of manganese or the dentition of anoplotherium. A rash clergyman once, without further equipment in natural history than some desultory reading, attacked the Darwinian theory in some sundry magazine articles, in which he made himself uncommonly merry at Huxley's expense. This was intended to draw the great man's fire; and as the batteries remained silent the author proceeded to write to Huxley, calling his attention to the articles, and at the same time, with mock modesty, asking advice as to the further study of these deep questions. Huxley's answer was brief and to the point: "Take a cockroach and dissect it!"

Too exclusive devotion, however, to scalpel and microscope may leave a man of science narrow and one-sided, dead to some of the most interesting aspects of human life. But Huxley was keenly alive in all directions, and would have enjoyed mastering all branches of knowledge if the days had only been long enough. He found rest and recreation in change of themes, and after a long day's scientific work at South Kensington would read Sybel's French Revolution, or Lange's History of Materialism, or the last new novel, until the witching hour of midnight. This reading was in various languages. Without a university education, Huxley had a remarkably good knowledge of Latin. He was fond of Spinoza, and every once in a while; in the course of our chats, he would exclaim, "Come, now, let's see what old Benedict has to say about it! There's no better man." Then he would take the book from its shelf, and while we both looked on the page he would give voice to his own comments in a broad liberal paraphrase that showed his sound and scholar-like appreciation of every point in the Latin text. A spirited and racy version it would have been had he ever undertaken to translate Spinoza. So I remember saying once, but he replied: "We must leave it for young Fred Pollock, whom I think you have seen; he is shy and doesn't say much, but I can tell you, whatever he does is sure to be amazingly good." They who are familiar with Sir Frederick Pollock's noble book on Spinoza, to say nothing of his other works, will recognize the truth of the prophecy.

Huxley had also a mastery of French, Italian, and German, and perhaps of some other modern languages. Angelo Heilprin says that he found him studying Russian, chiefly in order to acquire a thorough familiarity with the work of the great anatomist, Kovalevsky. How far he may have carried that study I know not; but his son tells us that it was also in middle life that he began Greek, in order to read at first hand Aristotle and the New Testament. To read Aristotle with critical discernment requires an extremely good knowledge of Greek; and if Huxley got so far as that, we need not be surprised at hearing that he could enjoy the Homeric poems in the original.

I suppose there were few topics in the heavens or on earth that did not get overhauled at that little library fireside. At one time it would be politics, and my friend would thank God that, whatever mistakes he might have made in life, he had never bowed the knee to either of those intolerable humbugs, Louis Napoleon or Benjamin Disraeli. Without admitting that the shifty Jew deserved to be placed on quite so low a plane as Hortense Beauharnais's feeble son, we can easily see how distasteful he would be to a man of Huxley's earnest and whole-souled directness. But antipathy to Disraeli did not in this case mean fondness for Gladstone. In later years, when Huxley was having his great controversy with Gladstone, we find him writing: "Seriously, it is to me a grave thing that the destinies of this country should at present be seriously influenced by a man who, whatever he may be in the affairs of which I am no judge, is nothing but a copious shuffler in those which I do understand." In 1873 there occurred a brief passage at arms between Gladstone and Herbert Spencer, in which the great statesman's intellect looked amusingly small and commonplace in contrast with the giant mind of the philosopher. The defeated party was left with no resources except rhetorical artifice to cover his retreat, and his general aspect was foxy, not to say jesuitical. At least so Huxley declared, and I thoroughly agreed with him. Yet surely it would be a very inadequate and unjust estimate of Gladstone which should set him down as a shuffler and there leave the matter. From the statesman's point of view it might be contended that Gladstone was exceptionally direct and frank. But a statesman is seldom, if ever, called upon to ascertain and exhibit the fundamental facts of a case without bias and in the disinterested mood which science demands of her votaries. The statesman's business is to accomplish sundry concrete political purposes, and he measures statements primarily, not by their truth, but by their availableness as means toward a practical end. Pure science cultivates a widely different habit of mind. One could no more expect a prime minister, as such, to understand Huxley's attitude in presence of a scientific problem than a deaf-mute to comprehend a symphony of Beethoven. Gladstone's aim was to score a point against his adversary, at whatever cost, whereas Huxley was as quick to detect his own mistakes as anybody else's; and such differences in temperament were scarcely compatible with mutual understanding.

If absolute loyalty to truth, involving complete self-abnegation in face of the evidence, be the ideal aim of the scientific inquirer, there have been few men in whom that ideal has been so perfectly realized as in Huxley. If ever he were tempted by some fancied charm of speculation to swerve a hair's breadth from the strict line of fact, the temptation was promptly slaughtered and made no sign. For intellectual integrity he was a spotless Sir Galahad. I believe there was nothing in life which he dreaded so much as the sin of allowing his reason to be hoodwinked by personal predilections, or whatever Francis Bacon would have called "idols of the cave." Closely connected with this ever present feeling was a holy horror of a priori convictions of logical necessity and of long festoons of deductive argument suspended from such airy supports. The prime necessity for him was to appeal at every step to observation and experiment, and in the absence of such verification to rest content with saying, "I do not know." It is to Huxley, I believe, that we owe the epithet "Agnostic," for which all men of scientific proclivities owe him a debt of gratitude, since it happened to please the popular fancy, and at once supplanted the label "Positivist," which used to be ruthlessly pasted upon all such men, in spite of their protests and struggles. No better word than "Agnostic" could be found to express Huxley's mental temperament, but with anything like a formulated system of agnosticism he had little more to do than with other "isms." He used to smile at the formidable parade which Lewes was making with his Objective Method and Verification, in which capital letters did duty for part of the argument; and as for Dean Mansel's elaborate agnosticism, in his Limits of Religious Thought, Huxley, taking a hint from Hogarth, used to liken him to a (theological) innkeeper who has climbed upon the signboard of the rival (scientific) inn, and is busily sawing it off, quite oblivious of the gruesome fact that he is sitting upon the unsupported end! But while he thus set little store by current agnostic metaphysics, Huxley's intellectual climate, if I may so speak, was one of perfect agnosticism. In intimate converse with him, he always seemed to me a thoroughgoing and splendid representative of Hume; indeed, in his writings he somewhere lets fall a remark expressing a higher regard for Hume than for Kant. It was at this point that we used to part company in our talks; so long as it was a question of Berkeley we were substantially agreed, but when it came to Hume we agreed to differ.

It is this complete agnosticism of temperament, added to his abiding dread of intellectual dishonesty, that explains Huxley's attitude toward belief in a future life. He was not a materialist; nobody saw more clearly than he the philosophic flimsiness of materialism, and he looked with strong disapproval upon the self-complacent negations of Ludwig Buechner. Nevertheless, with regard to the belief in an immortal soul his position was avowedly agnostic, with perhaps just the slightest possible tacit though reluctant leaning toward the negative. This slight bias was apparently due to two causes. First, it is practically beyond the power of science to adduce evidence in support of the soul's survival of the body, since the whole question lies beyond the bounds of our terrestrial experience. Huxley was the last man to assume that the possibilities of nature are limited by our experience, and I think he would have seen the force of the argument that, in questions where evidence is in the nature of the case inaccessible, our inability to produce it does not afford even the slighest prima facie ground for a negative verdict.[1] Nevertheless, he seems to have felt as if the absence of evidence did afford some such prima facie ground, for in a letter to Charles Kingsley, written in 1860, soon after the sudden death of his first child, he says: "Had I lived a couple of centuries earlier, I could have fancied a devil scoffing at me . . . and asking me what profit it was to have stripped myself of the hopes and consolations of the mass of mankind; to which my only reply was, and is, O devil! truth is better than much profit. I have searched over the grounds of my belief, and if wife and child and name and fame were all to be lost to me, one after the other, as the penalty, still I will not lie." This striking declaration shows that the second cause of the bias was the dread of self-deception. It was a noble exhibition of intellectual honesty raised to a truly Puritanic fervor of self-abnegation. Just because life is sweet, and the love of it well-nigh irrepressible, must all such feelings be suspected as tempters, and frowned out of our temple of philosophy. Rather than run any risk of accepting a belief because it is pleasant, let us incur whatever chance

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[1] I have explained this point at some length in The Unseen World, pp. 43–53.

there may be of error in the opposite direction; thus we shall at least avoid the one unpardonable sin. Such, I think, was the shape which the case assumed in Huxley's mind. To me it takes a very different shape; but I can not help feeling that mankind is going to be helped by such stanch intellectual integrity as his far more than it is going to be helped by consoling doctrines of whatever sort; and therefore his noble self-abnegation, even though it may have been greater than was called for, is worthy of most profound and solemn homage.

But we did not spend the whole of the evening in the little library. Brierwood and Havana at length gave out, and the drawing-room had its claims upon us. There was a fondness for music in the family, and it was no unusual thing for us to gather around the piano and sing psalms, after which there would perhaps be a Beethoven sonata, or one of Chopin's nocturnes, or perhaps a song. I can never forget the rich contralto voice of one bright and charming daughter, since passed away, or the refrain of an old-fashioned song which she sometimes sang about "My love, that loved me long ago." From music it was an easy transition to scraps of Browning or Goethe, leading to various disquisitions. Of mirth and badinage there was always plenty. I dare say there was not another room in London where so much exuberant nonsense might have been heard. It is no uncommon thing for masters of the Queen's English to delight in torturing it, and Huxley enjoyed that sort of pastime as much as James Russell Lowell. "Smole" and "declone" were specimens of the preterits that used to fall from his lips; and as for puns, the air was blue with them. I can not recall one of them now, but the following example, from a letter of 1855 inviting Hooker to his wedding, will suffice to show the quality: "I terminate my Baccalaureate and take my degree of M. A. trimony (isn't that atrocious?) on Saturday, July 21."

One evening the conversation happened to touch upon the memorable murder of Dr. Parkman by Dr. Webster, and I expressed some surprise that an expert chemist like Webster should have been so slow in getting his victim's remains out of the way. "Well," quoth Huxley, "there's a good deal of substance in a human body. It isn't easy to dispose of so much corpus delicti a reflection which has frequently deterred me when on the point of killing somebody." At such remarks a soft ripple of laughter would run about the room, with murmurs of "Oh, Pater!" It was just the same in his lectures to his students. In the simple old experiment illustrating reflex action a frog, whose brain had been removed, was touched upon the right side of the back with a slightly irritating acid, and would forthwith reach up with his right hind leg and rub the place. The next thing in order was to tie the right leg, whereupon the left leg would come up, and by dint of strenuous effort reach the itching spot. One day the stretching was so violent as to result in a particularly elaborate and comical somersault on the part of the frog, whereupon Huxley exclaimed, "You see, it doesn't require much of a brain to be an acrobat!" In an examination on anatomy a very callow lad got the valves of the heart wrong, putting the mitral on the right side; but Huxley took compassion on him, with the remark, "Poor little beggar! I never got them correctly myself until I reflected that a bishop was never in the right!" On another occasion, at the end of a lecture, he asked one of the students if he understood it all. The student replied, "All, sir, but one part, during which you stood between me and the blackboard." "Ah," rejoined Huxley, "I did my best to make myself clear, but could not make myself transparent!"[1]

Probably the most tedious bore on earth is the man who feels it incumbent on him always to be facetious and to turn everything into a joke. Lynch law is about the right sort of thing for such persons. Huxley had nothing in common with them. His drollery was the spontaneous bubbling over of the seething fountains of energy. The world's strongest spirits, from Shakespeare down, have been noted for playfulness. The prim and sober creatures who know neither how to poke fun nor to take it are apt to be the persons who are ridden by their work—useful mortals after their fashion, mayhap, but not interesting or stimulating. Huxley's playfulness lightened the burden of life for himself and for all with whom he came in contact. I seem to see him now, looking up from his end of the table—for my place was usually at Mrs. Huxley's end—his dark eyes kindling under their shaggy brows, and a smile of indescribable beauty spreading over the swarthy face, as prelude to some keen and pithy but never unkind remark. Electric in energy, formidable in his incisiveness, he smote hard; but there was nothing cruel about him, nor did he ever inflict pain through heedless remarks. That would have been a stupidity of which he was incapable. His quickness and sureness of perception, joined with his abounding kindliness, made him a man of almost infinite tact. I had not known him long before I felt that the ruling characteristic in his nature was tenderness. He reminded me of one of Charles Reade's heroes, Colonel Dujardin, who had the eye of a hawk, but down somewhere in the depths of that eye of a hawk there was the eye of a dove. It was chiefly the sympathetic quality in the man that exerted upon me an ever-strengthening spell. My experiences in visiting him had one notable feature, which I found it hard to interpret. After leaving the house, at the close of a Sunday evening, the outside world used to seem cold and lonely for being cut off from that presence; yet on the next Sunday, at the moment of his cordial greeting, a feeling always came over me that up to that moment I had

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[1] I have here eked out my own reminiscences by instances cited from Leonard Huxley's book.

never fully taken in how lovable he was; I had never quite done him justice. In other words, no matter how vivid the image which I carried about in my mind, it instantly seemed dim and poor in presence of the reality. Such feelings are known to lovers; in other relations of life they are surely unusual. I was speaking about this to my dear old friend, the late Alexander Macmillan, when he suddenly exclaimed: "You may well feel so, my boy. I tell you, there is so much real Christianity in Huxley that if it were parceled out among all the men, women, and children in the British Islands there would be enough to save the soul of every one of them, and plenty to spare!"

I have said that Huxley was never unkind; it is perhaps hardly necessary to tell his readers that he could be sharp and severe, if the occasion required. I have heard his wife say that he never would allow himself to be preyed upon by bores, and knew well how to get rid of them. Some years after the time of which I have been writing I dined one evening at the Savile Club with Huxley, Spencer, and James Sime. As we were chatting over our coffee, some person unknown to us came in and sat down on a sofa near by. Presently this man, becoming interested in the conversation, cut short one of our party and addressed a silly remark to Spencer in reply to something which he had been saying. Spencer's answer was civil, but brief, and not inviting. Nothing abashed, the stranger kept on and persisted in forcing himself into the conversation, despite our bleak frowns and arctic glances. It was plain that something must be done, and while the intruder was aiming a question directly at Huxley the latter turned his back upon him. This was intelligible even to assinine apprehension, and the remainder of our evening was unmolested.

I never knew (not being inquisitive) just when the Huxleys began having their "tall teas" on Sunday evenings; but during that first winter I seldom met any visitors at their house, except once or twice Ray Lankester and Michael Foster. Afterwards Huxley, with his wife, on their visit to America, spent a few summer days with my family at Petersham, where the great naturalist learned for the first time what a tin dipper is. Once, in London, in speaking about the starry heavens, I had said that I never could make head or tail of any constellation except the Dipper, and of course everybody must recognize in that the resemblance to a dipper. To my surprise one of the young ladies asked, "What is a dipper?" My effort at explanation went far enough to evoke the idea of "a ladle," but with that approximation I was fain to let the matter rest until that August day in New England, when, after a tramp in the woods, my friends quaffed cool mountain water from a dipper, and I was told that not only the name, but the thing, is a Yankee notion.

Some time after this I made several visits to England, giving lectures at the Royal Institution and elsewhere, and saw the Huxleys often, and on one occasion, with my wife, spent a fortnight or so at their home in Marlborough Place. The Sunday evenings had come to be a time for receiving friends, without any of the formality that often attaches to "receptions." Half a dozen or more would drop in for the "high tea." I then noticed the change in the adjective, and observed that the phrase and the institution were not absolutely confined to the Huxley household; but their origin is still for me enshrouded in mystery, like the "empire of the Toltecs." After the informal and jolly supper others would come in, until the company might number from twenty to thirty. Among the men whom I recall to mind (the married ones accompanied by their wives, of course), were Mark Pattison, Lecky, and J. R. Green, Burdon Sanderson and Lauder Brunton, Alma Tadema, Sir James Stephen and his brother Leslie, Sir Frederick Pollock, Lord Arthur Russell, Frederic Harrison, Spencer Walpole, Romanes, and Ralston. Some of these I met for the first time; others were old friends. Nothing could be more charming than the graceful simplicity with which all were entertained, nor could anything be more evident than the affectionate veneration which everybody felt for the host.

The last time that I saw my dear friend was early in 1883, just before coming home to America. I found him lying on the sofa, too ill to say much, but not too ill for a jest or two at his own expense. The series of ailments had begun which were to follow him for the rest of his days. I was much concerned about him, but journeys to England had come to seem such a simple matter that the thought of its being our last meeting never entered my mind. A few letters passed back and forth with the lapse of years, the last one (in 1894) inquiring when I was likely to be able to come and visit him in the pretty home which he had made in Sussex, where he was busy with "digging in the garden and spoiling grandchildren." When the news of the end came, it was as a sudden and desolating shock.

There were few magazines or newspapers which did not contain articles about Huxley, and in general those articles were considerably more than the customary obituary notice. They were apt to be more animated than usual, as if they had caught something from the blithe spirit of the man; and they gave so many details as to show the warm and widespread interest with which he was regarded. One thing, however, especially struck me. While the writers of these articles seemed familiar with Huxley's philosophical and literary writings, with his popular lectures on scientific subjects and his controversies with sundry clergymen, they seemed to know nothing whatever about his original scientific work. It was really a singular spectacle, if one pauses to think about it. Here are a score of writers engaged in paying tribute to a man as one of the great scientific lights of the age, and yet, while they all know something about what he would have considered his fugitive work, not one of them so much as alludes to the cardinal achievements in virtue of which his name marks an epoch! It is very much as if the biographers of Newton were to enlarge upon his official labors at the mint and his theory of light, while preserving a dead silence as to gravitation and fluxions. A few words concerning Huxley's work will therefore not seem superfluous. A few words are all that can here be given; I can not pretend even to make a well-rounded sketch.

In one respect there was a curious similarity between the beginnings of Huxley's scientific career and of Darwin's. Both went, as young men, on long voyages into the southern hemisphere in ships of the royal navy, and from the study of organisms encountered on these voyages both were led to theories of vast importance. Huxley studied with keen interest and infinite patience the jellyfish and polyps floating on the surface of the tropical seas through which his ship passed. Without books or advisers, and with scant aid of any sort except his microscope, which had to be tied to keep it steady, he scrutinized and dissected these lowly forms of life, and made drawings and diagrams illustrating the intricacies of their structure, until he was able, by comparison, to attain some very interesting results. During four years, he says, "I sent home communication after communication to the Linnæan Society, with the same result as that obtained by Noah when he sent the raven out of his ark. Tired at last of hearing nothing about them, I determined to do or die, and in 1849 I drew up a more elaborate paper, and forwarded it to the Royal Society." This was a memoir On the Anatomy and the Affinities of the Family of Medusæ; and it proved to be his dove, though he did not know it until his return to England, a year later. Then he found that his paper had been published, and in 1851, at the age of 26, he was made a Fellow of the Royal Society. He went on writing papers giving sundry results of his observations, and the very next year received the society's royal medal, a supreme distinction which he shared with Joule, Stokes, and Humboldt. In the address upon the presentation of the medal, the president, Lord Rosse, declared that Huxley had not only for the first time adequately described the Medusæ and laid down rational principles for classifying them, but had inaugurated "a process of reasoning, the results of which can scarcely yet be anticipated, but must bear in a very important degree upon some of the most abstruse points of what may be called transcendental physiology."

In other words, the youthful Huxley had made a discovery that went to the bottom of things; and as in most if not all such cases, he had enlarged our knowledge not only of facts, but of methods. It was the beginning of a profound reconstruction of the classification of animals, extinct and living. In the earlier half of the century the truest classification was Cuvier's. That great genius emancipated himself from the notion that groups of animals should be arranged in an ascending or descending series, and he fully proved the existence of three divergent types—Vertebrata, Mollusca, and Articulata. Some of the multitude of animals lower or less specialized than these he grouped by mistake along with Mollusca or Articulata, while all the rest he threw into a fourth class, which he called Radiata. It was evident that this type was far less clearly defined than the three higher types. In fact, it was open to the same kind of objection that used to be effectively urged against Max Muller's so-called Turanian group of languages; it was merely a negation. Radiata were simply animals that were neither Articulata nor Mollusca nor Vertebrata; in short, they were a motley multitude, about which there was a prevailing confusion of ideas at the time when young Huxley began the study of jellyfish.

We all know how it was the work of the great Esthonian embryologist, Baer, that turned Herbert Spencer toward his discovery of the law of evolution. It is therefore doubly interesting to know that in these early studies Huxley also profited by his knowledge of Baer's methods and results. It all tended toward a theory of evolution, although Baer himself never got so far as evolution in the modern sense; and as for Huxley, when he studied Medusæ, he was not concerned with any general theory whatever, but only with putting into shape what he saw.

And what he saw was that throughout their development the Medusæ consist of two foundation membranes or delicate web-like tissues of cells—one forming the outer integument, the other doing duty as stomach lining—and that there was no true body cavity with blood vessels. He showed that groups apparently quite dissimilar, such as the hydroid and sertularian polyps, the Physophoridæ and sea anemones, are constructed upon the same plan; and so he built up his famous group of Cœlenterata, or animals with only a stomach cavity, as contrasted with all higher organisms, which might be called Cœlomata, or animals with a true body cavity containing a stomach with other viscera and blood vessels. In all Cœlomata, from the worm up to man, there is a third foundation membrane. Thus the Cuvierian group of Radiata was broken up, and the way was prepared for this far more profound and true arrangement: (1) Protozoa, such as the amœba and sponges, in which there is no distinct separation of parts performing different functions; (2) Cœlenterata, in which there is a simple differentiation between the inside which accumulates energy and the outside which expends it; and (3) Cœlomata, in which the inside contains a more or less elaborate system of distinct organs devoted to nutrition and reproduction, while the outside is more or less differentiated into limbs and sense organs for interaction with the outer world. Though not yet an evolutionist, Huxley could not repress the prophetic thought that Cœlenterata are ancient survivals, representing a stage through which higher animal types must once have passed.

As further elaborated by Huxley, the development above the cœlenterate stage goes on in divergent lines; stopping abruptly in some directions, in others going on to great lengths. Thus, in the direction taken by echinoderms, the physical possibilities are speedily exhausted, and we stop with starfishes and holothurians. But among Annuloida, as Huxley called them, there is more flexibility, and we keep on till we reach the true Articulata in the highly specialized insects, arachnoids, and crustaceans. It is still more interesting to follow the Molluscoida, through which we are led, on the one hand, to the true Mollusca, reaching their culmination in the nautilus and octopus, and on the other hand, to the Tunicata, and so on to the vertebrates.

In the comparative anatomy of vertebrates, also, Huxley's achievements were in a high degree original and remarkable. First in importance, perhaps, was his classification of birds, in which their true position and relationships were for the first time disclosed. Huxley showed that all birds, extinct and living, must be arranged in three groups, of which the first is represented by the fossil archæopteryx, with its hand-like wing and lizard-like tail; the second by the ostrich and its congeners, and the third by all other living birds. He further demonstrated the peculiarly close relationship between birds and reptiles through the extinct dinosaurs. In all these matters his powerful originality was shown in the methods by which these important results were reached. Every new investigation which he made seemed to do something toward raising the study of biology to a higher plane, as, for example, his celebrated controversy with Owen on the true nature of the vertebrate skull. The mention of Owen reminds us that it was also Huxley who overthrew Cuvier's order of Quadrumana by proving that apes are not four handed, but have two hands and two feet; he showed that neither in limbs nor in brain does man present differences from other primates that are of higher than generic value. Indeed, there were few corners of the animal world, past or present, which Huxley did not at some time or other overhaul, and to our knowledge of which he did not make contributions of prime importance. The instances here cited may serve to show the kind of work which he did, but my mention of them is necessarily meager. In the department of classification, the significance of which has been increased tenfold by the doctrine of evolution, his name must surely rank foremost among the successors of the mighty Cuvier.

Before 1860 the vastness and accuracy of Huxley's acquirements and the soundness of his judgment were well understood by the men of his profession, insomuch that Charles Darwin, when about to publish The Origin of Species, said that there were three men in England upon whose judgment he relied; if he could convince those three, he could afford to wait for the rest. The three were Lyell, Hooker, and

Huxley, and he convinced them. How sturdily Huxley fought Darwin's battles is inspiring to remember. Darwin rather shrank from controversy, and, while he welcomed candid criticism, seldom took any notice of ill-natured attacks. On one occasion, nevertheless, a somewhat ugly assault moved Darwin to turn and rend the assailant, which was easily and neatly done in two pages at the end of a scientific paper. Before publishing the paper, however, Darwin sent it to Huxley, authorizing him to omit the two pages if he should think it best. Huxley promptly canceled them, and sent Darwin a delicious little note, saying that the retort was so excellent that if it had been his own he should hardly have had virtue enough to suppress it; but although it was well deserved, he thought it would be better to refrain. "If I say a savage thing, it is only 'pretty Fanny's way;' but if you do, it is not likely to be forgotten." There was a friend worth having.

There can be little doubt, I think, that, without a particle of rancor, Huxley did keenly feel the gaudium certaminis. He exclaimed among the trumpets, Ha! ha! and was sure to be in the thickest of the fight. His family seemed to think that the "Gladstonian dose" had a tonic effect upon him. When he felt too ill for scientific work, he was quite ready for a scrimmage with his friends, the bishops. Not caring much for episcopophagy (as Huxley once called it), and feeling that controversy of that sort was but a slaying of the slain, I used to grudge the time that was given to it, and taken from other things. In 1879 he showed me the synopsis of a projected book on The Dog, which was to be an original contribution to the phylogenetic history of the order Carnivora. The reader who recalls his book on The Crayfish may realize what such a book about dogs would have been. It was interrupted and deferred and finally pushed aside by the thousand and one duties and cares that were thrust upon him—work on government commissions, educational work, parish work, everything that a self-sacrificing and public-spirited man could be loaded with. In the later years, whenever I opened a magazine and found one of the controversial articles I read it with pleasure, but sighed for the dog book.

I dare say, though, it was all for the best. "To smite all humbugs, however big; to give a nobler tone to science; to set an example of abstinence from petty personal controversies, and of toleration for everything but lying; to be indifferent as to whether the work is recognized as mine or not, so long as it is done"—such were Huxley's aims in life. And for these things, in the words of good Ben Jonson, "I loved the man, and do honor to his memory, on this side idolatry, as much as any."

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