45TH CONGRESS, 3d Session. } SENATE. { MIS. DOC. No. 59.

ANNUAL REPORT

OF THE

BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION,

SHOWING THE

OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION FOR THE YEAR

1878.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1879.

FORTY-FIFTH CONGRESS—THIRD SESSION.

IN THE SENATE OF THE UNITED STATES,
March 3, 1879.

The following resolution was agreed to by the Senate February 10, 1879, and concurred in by the House of Representatives March 3, 1879:

Resolved by the Senate (the House of Representatives concurring), That 10,500 copies of the Report of the Smithsonian Institution for the year 1878 be printed, 1,000 copies of which shall be for the use of the Senate, 3,000 copies of which shall be for the use of the House of Representatives, and 6,500 for the use of the Smithsonian Institution.

Attest:

GEO. C. GORHAM,
Secretary.

LETTER

FROM THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

TRANSMITTING

The annual report of the Institution for the year 1878.

FEBRUARY 8, 1879.—Ordered to be printed.

SMITHSONIAN INSTITUTION,
February 7, 1879.

SIR: In behalf of the Board of Regents, I have the honor to submit to the Congress of the United States the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year 1878.

I have the honor to be, your obedient servant,

SPENCER F. BAIRD,
Secretary Smithsonian Institution.

Hon. W. A. WHEELER,
President of the Senate.

ANNUAL REPORT OF THE SMITHSONIAN INSTITUTION FOR 1878.

This document contains:

1. The annual report of the Secretary, giving an account of the operations and condition of the establishment for the year 1878, with the statistics of collections, exchanges, &c.

2. The report of the Executive Committee, exhibiting the financial affairs of the Institution, including a statement of the Smithson fund, the receipts and expenditures for the year 1878, and the estimates for 1879.

3. The proceedings of the Board of Regents for the sessions of May, 1878, and January, 1879.

4. A general appendix, including translations from foreign journals or works not generally accessible, but of interest to the collaborators and correspondents of the Institution, teachers, and others interested in the promotion of knowledge.

THE SMITHSONIAN INSTITUTION.

RUTHERFORD B. HAYES, President of the United States, *ex officio* Presiding Officer.
MORRISON R. WAITE, Chief Justice of the United States, Chancellor of the Institution (President of the Board of Regents).
SPENCER F. BAIRD, Secretary (Director of the Institution).
WILLIAM J. RHEES, Chief Clerk.

REGENTS OF THE INSTITUTION.

MORRISON R. WAITE, Chief Justice of the United States.
WILLIAM A. WHEELER, Vice-President of the United States.
HANNIBAL HAMLIN, member of the Senate of the United States.
AARON A. SARGENT, member of the Senate of the United States.
ROBERT E. WITHERS, member of the Senate of the United States.
HIESTER CLYMER, member of the House of Representatives.
ALEXANDER H. STEPHENS, member of the House of Representatives.
JAMES A. GARFIELD, member of the House of Representatives.
JOHN MACLEAN, citizen of New Jersey.
PETER PARKER, citizen of Washington, D. C.
ASA GRAY, citizen of Massachusetts.
HENRY COPPÉE, citizen of Pennsylvania.
WILLIAM T. SHERMAN, citizen of Washington, D. C.
NOAH PORTER, citizen of Connecticut.

EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS.

PETER PARKER. JOHN MACLEAN. WILLIAM T. SHERMAN.

MEMBERS EX-OFFICIO OF THE INSTITUTION.

RUTHERFORD B. HAYES, President of the United States.
WILLIAM A. WHEELER, Vice-President of the United States.
MORRISON R. WAITE, Chief Justice of the United States.
WILLIAM M. EVARTS, Secretary of State.
JOHN SHERMAN, Secretary of the Treasury.
GEORGE W. McCRARY, Secretary of War.
RICHARD W. THOMPSON, Secretary of the Navy.
DAVID M. KEY, Postmaster-General.
CARL SCHURZ, Secretary of the Interior.
CHARLES DEVENS, Attorney-General.
H. E. PAINE, Commissioner of Patents.

OFFICERS AND ASSISTANTS OF THE SMITHSONIAN INSTITUTION AND NATIONAL MUSEUM, JANUARY, 1879.

SPENCER F. BAIRD,
Secretary, Director of the Institution.
WILLIAM J. RHEES,
Chief Clerk.
DANIEL LEECH,
Clerk, Correspondence.
CLARENCE B. YOUNG,
Clerk, Accounts.
HERMANN DIEBITSCH,
Clerk, Foreign Exchanges.
JANE A. TURNER,
Clerk, Library.
MAGGIE E. GRIFFIN,
Clerk, Distribution of Publications.
SOLOMON G. BROWN,
Clerk, Transportation.

G. BROWN GOODE,
Curator of the Museum.
F. M. ENDLICH,
Assistant, Mineralogy.
ROBT. RIDGWAY,
Assistant, Ornithology.
TARLETON H. BEAN,
Assistant, Ichthyology.
CHAS. RAU,
Assistant, Archæology.
EDWARD FOREMAN,
Assistant, Ethnology.
F. H. CUSHING,
Assistant, Ethnology.

JOSEPH PALMER,
Taxidermist.
T. W. SMILLIE,
Photographer.
JOSEPH HERRON,
Janitor.

REPORT OF PROFESSOR BAIRD,

SECRETARY OF THE SMITHSONIAN INSTITUTION, FOR 1878.

To the Board of Regents of the Smithsonian Institution:

GENTLEMEN: I have the honor herewith to present the report of the operations and condition of the Smithsonian Institution for the year 1878.

The most important event during that time, and, indeed, in the history of the establishment, is the death of Professor Henry, its lamented Secretary, to whom was intrusted its organization in 1846, and under whose firm and judicious direction it has been carried safely forward, surmounting in its progress many obstacles and trials, to its present condition of efficiency and prosperity.

It is difficult to overestimate the importance to science and humanity of the administration of Professor Henry in this connection. It was a mere chance that the right man for the place would be selected, and whether any other of the candidates would have done equally well it is, of course, impossible to say. It is very certain, however, that the chances would have been adverse to such a result. The most logical methods of operation and research, the strictest economy of administration, the restriction of the Institution to its legitimate functions in the increase and diffusion of knowledge among men, and the avoidance of all entangling alliances of every kind, signally characterized the administration of affairs by Professor Henry for the long period of nearly one third of a century. This time sufficed to impress upon the Institution a definite policy, and one which will, I trust, be permanent. It will certainly be my endeavor, as the successor of Professor Henry, to carry out his principles during whatever period Providence and your good-will may grant me the direction of affairs.

The characteristics of the policy adopted by Professor Henry at the beginning of his administration, and sanctioned by the Board of Regents, were, first, never to attempt to do with the funds and appliances of the Institution what could equally well be done by other appropriate agencies; secondly, to attempt nothing which might not strictly be considered as coming within the department of science, theoretical or applied; thirdly, to keep all expenditures within the income of the Institution, and never to allow the operations of one year to be hampered by indebtedness carried over from the preceding; and, finally, not to restrict the operations of the institution to Washington, or even to the United States; but to extend its benefits to the whole world, in view of the proper interpretation of the will of Mr. Smithson that the main functions of the institution should be "the increase and diffusion of knowledge among men."

Numerous illustrations of the policy of Professor Henry in regard to the first principle adopted by him can be adduced. No matter how favorite the branch of research might have been with him, nor what amount of reputation might be gained to the Institution by prosecuting it, he was always ready to transfer it to those who could carry it on with success. The most noteworthy instance, perhaps, was that in connection with the subject of meteorology, which had from the beginning been one of special interest to him. The very earliest action in the scientific direction of the Institution had reference to the adoption of a general system of meteorological observations throughout the United States and the adjacent portions of America, and the proper reduction of the results in a systematic form. Up to the time of the establishment of the Signal Office, this was by far the most important feature of Smithsonian activity. It embraced a connection with about six hundred observers from all the walks of life and in all parts of the country. With these, constant communication was held, and from them were received monthly detailed observations of various degrees of minuteness and accuracy on blanks furnished to them previously by the Institution; and an extended correspondence was maintained with them, not only on meteorological subjects but upon others of scientific interest. For more than twenty-five years this relation continued with the most important results, the work extending and enlarging year by year in a rapid ratio.

As soon as the operations of the United States Signal Office were established by government, under General Myer, Professor Henry offered to turn over the Smithsonian system with its observers to that establishment, and this offer being accepted the transfer was made; since then the Institution has confined itself to working up the results of a quarter of a century's labors and publishing them in a systematic and digested form. The series of such digests has been nearly completed and the whole will be finished as rapidly as the funds of the Institution will permit.

It was to this restriction of effort to subjects of importance, in a scientific or practical point of view, which were not otherwise provided for, that is due the impression made upon the progress of learning by the Smithsonian Institution as administered by Professor Henry. There are numerous establishments in the United States, not of precisely similar character, but with the same general object, and with equal or larger funds of endowment, but which are scarcely known or even heard of outside of the limits of the city in which they may happen to be situated. The name of the Smithsonian Institution, on the contrary, is a familiar one in every part of the world; and it may almost be said that it is even better understood, comprehended, and appreciated in the remotest parts of Europe than it is in some sections of the United States.

At the beginning of the active operations of the institution, Professor Henry prepared what he called a "Programme of organization." This was first submitted to the judgment of leading men of science throughout the United States and Europe, and received general approval. It was presented to the Board, and adopted as the basis of future operations. It is interesting to note that whatever new lines of research or of practical work have been taken up from time to time by the Institution, were simply the carrying out into practical effect of one or other of the subdivisions of the proposed programme.

The board at its special meeting, held on the 17th of May, 1878, directed the preparation of a suitable biography of its late Secretary, and also the holding of a memorial service in one of the halls of Congress, if it could be obtained for the purpose. The preparation of this biography was intrusted to a committee, consisting of President Porter, of Yale College, Dr. Maclean, of Princeton, and Professor Gray, of Harvard; and it has been prepared by the latter gentleman, and will be submitted by him to the Board.

The arrangements for the memorial services have been made, to take place on the evening of Thursday, January 16, 1879. In addition to the records prepared by the direction of the Board, two other memoirs have been written, and were presented, October 26, 1878, to the Philosophical Society of Washington, of which Professor Henry had been the presiding officer from the time of its organization. One of these memoirs, by Dr. Welling, president of Columbian University, gave an account of Professor Henry's life and character with reference to his personal, social, and educational qualities; and the other, by Mr. William B. Taylor, set forth more particularly his scientific work and the succession of his discoveries.

Professor Henry's last illness dates from the autumn of the year 1877, and was apparently induced in a considerable measure by exposure while carrying on a series of experiments in behalf of the Light-House Board. After his return from Staten Island, he was able to bestow but little attention to the details of the work of the Institution; although, up to the very day of his death, he was directing and controlling it as from the beginning. Shortly after his return in the autumn, he made a visit to Philadelphia, for the purpose of being under the care of Dr. S. Weir Mitchell, and came back to Washington after an absence of a few weeks. His death took place on the 13th of May, 1878,—a peaceful and happy death—surrounded by his family and friends.

After his decease, as in his life, he was signally honored. Congress adjourned to attend the funeral, which was also marked by the presence of the highest dignitaries of the country, including the President and his cabinet, the justices of the Supreme Court of the United States, and those of the District of Columbia, the diplomatic corps, and numerous organizations of which he was a member, as well as others from abroad.

Honored by the Board in being selected to succeed Professor Henry, it was with the greatest diffidence, and with an unaffected distrust in my ability to administer worthily the operations of the Institution, that I accepted the trust. Animated by a desire to secure the continuance of the wise policy inaugurated and maintained by Professor Henry,—by a consciousness of familiarity with the varied duties required,—and by a natural sympathy of purpose resulting from a long association with him—holding steadily before me his example—I venture upon the experiment; hoping only that the contrast of the present administration of the Institution with that of the past will not be too unfavorably marked.

I may, perhaps, be pardoned for calling attention to the fact that my own connection with the Institution and association with Professor Henry dates back to the year 1850, and that consequently, for more than twenty-eight years, I have been engaged in carrying out the principles established by the late Secretary, and that the details of administration, and the general plans of operation, are consequently not unfamiliar to me. My association has indeed been, indirectly, longer than the time mentioned, since as early as 1848 I visited Professor Henry and was engaged by him to carry out certain researches in reference to the natural history of Pennsylvania, aided by a grant of money from the funds of the Institution, for the purpose.

Although the fact of the death of Professor Henry was promptly spread over the United States and transmitted throughout the Old World by means of the telegraph, it was thought proper, in accordance with the usage of similar establishments, to make a formal announcement by a circular letter, addressed to the foreign correspondents of the Institution. A circular was accordingly prepared in the name of the Chancellor and widely distributed. This has elicited a great number of responses, containing gratifying expressions of condolence and sympathy.

The regular session of the Board of Regents for the winter of 1877 was held in January, 1878, at which time the report for 1877 was presented by Professor Henry and approved. An extra meeting was called on the 17th of May, on the day after Professor Henry's funeral, at which an election of his successor took place, and arrangements were made for a proper eulogy and the memorial meeting in January, 1879.

The law of Congress establishing and organizing the Smithsonian Institution makes no provision for the discharge of the duties of the chief officer by any person other than the Secretary; and as no bills for services, for salaries, labor, supplies, &c., can be paid without his indorsement, the disability or death of the Secretary during the recess of the meetings of the Board is likely to involve very serious difficulties. For the purpose of providing for this contingency, Senator Hamlin, a Regent of the Institution, has introduced a joint resolution into the Senate, providing that in case of the death, disability, or absence of the Secretary, the Chancellor be empowered to appoint some one to discharge his duties until any necessary provision can be made by the Board in full session, it not being expected that the Board could be brought together outside of the period of the meeting of Congress. This resolution has already passed the Senate, and it is hoped will soon pass the House and become a law.

The only change in the Board of Regents to be placed on record is the resignation of Mr. Bancroft and the election of General Sherman, a former Regent, to fill his place. General Sherman was also elected by the Board at its special meeting of the 17th of May to serve as one of the Executive Committee.

The continued expansion of the operations of the Institution, especially those connected with its department of international exchanges, has called for accommodations more extended than those that have been available; and Professor Henry, for some time before his death, had in contemplation a removal from that portion of the building occupied by his family, to a private residence in the city. He was considering this question more urgently when his illness supervened, and of course interrupted any further action on his part.

Although the occupation of the east wing of the building free of rent was one of the privileges of the Secretary of the Institution, I found that all the rooms in the building could be used to great advantage as offices of the Institution; and I therefore determined, with the consent of the members of the Executive Committee, to devote them to that purpose. A door was opened in the wall separating the present rooms from the apartments adjacent to them, and some other trifling inexpensive alterations were made, by which the entire house was transformed into a series of offices and work-rooms. Every room is now in use, and the entire force of clerks and employés has been concentrated in the east range and wing, so that they are closely connected in their work, adding very greatly to the efficiency of operations.

A system of electric bells and telephones has been established throughout the building, by means of which instant communication can be had between the several offices and work-rooms without involving the loss of time required to pass from one to another, or without calling any one from his work.

FINANCES.

In the report of the Executive Committee will be found a detailed statement of the finances of the Institution, which are believed to be in a satisfactory state. The amount to the credit of the late Secretary at the time of his death was $8,522.98. This was transferred on the 28th of May, 1878, to the credit of his successor, with whom a new account was opened at the Treasury. The premium on the gold-bearing interest of the Smithsonian endowment, which has heretofore constituted a more or less prominent item of the receipts for the year, has, of course, disappeared; only a small percentage having been realized on the July payment. As the natural counterpart to this, however, the reduction in the price of labor and the decrease in the cost of many articles of general supply leaves the Institution in a correspondingly better financial condition than before.

The following is a statement of the condition of the Smithson fund at the beginning of the year 1879:

The amount originally received as the bequest of James Smithson, of England, deposited in the Treasury of the United States in accordance with the act of Congress of August 10, 1846	$515,169 00
The residuary legacy of Smithson, received in 1865, deposited in the Treasury of the United States in accordance with the act of Congress of February 8, 1867	26,210 63
Total bequest of Smithson	541,379 63
Amount deposited in the Treasury of the United States, as authorized by act of Congress of February 8, 1867, derived from savings of income and increase in value of investments	108,620 37
Amount received as the bequest of James Hamilton, of Carlisle, Pa., February 24, 1874	1,000 00
Total permanent Smithson fund in the Treasury of the United States, bearing interest at 6 per cent., payable semi-annually in gold	651,000 00
In addition to the above, there remains of the extra fund from savings, &c., in Virginia bonds and certificates, viz: Consolidated bonds, $58,700; deferred certificates, $29,375.07; fractional certificate, $50.13; total, $88,125.20, valued January, 1879, at	34,000 00
Cash balance in United States Treasury at the beginning of the year 1879, for current expenses	19,632 57
Total Smithson funds January 8, 1879	704,632 57

BUILDING.

Some damage was done to the Smithsonian building by the severe storms of the summer of 1878, and considerable expense incurred in repairs. The finial on the west tower was blown off and a large number of slates torn away, all of which required reconstruction. The occasion was taken to give the gutters, spouts, and lightning-rods a thorough overhauling, leaving everything, it is believed, in the best condition. The basement has been cleaned and whitewashed, and all unserviceable material, including scrap-iron, &c., has been suitably disposed of.

PUBLICATIONS.

As has been frequently stated in former reports, the publications of the Institution consist of three classes: The first, the "Smithsonian Contributions to Knowledge"; the second, the "Smithsonian Miscellaneous

Collections"; and the third, the "Annual Reports of the Regents" of the Institution. The works of the first class, the Smithsonian Contributions to Knowledge, are published in quarto form, and are intended to embrace original memoirs, either the result of special investigations authorized and directed by the Institution, or prosecuted under other auspices and presented to it. The works of the second class, the Miscellaneous Collections, are similar in plan and construction to the "Contributions," but are in octavo form, and embrace more particularly monographic and descriptive papers in natural history, formal or systematic lists of species of animals or plants, physical tables, reports on the present state of knowledge in some department of physical or biologic science, &c. As with the "Contributions," each volume is composed of several distinct and independent papers, having no necessary connection with each other, the collection being determined chiefly by the aggregate number of pages suitable for a volume of average size. The average number of pages in the quarto volume is about 600; in the octavo volume, about 800. Each paper or memoir in either class is separately paged and indexed, with its own title-page, so as to be complete in itself, and separately distributed according to its subject. Of the quarto "Contributions," twenty-one volumes, and of the "Collections," fifteen volumes have been published.

The Smithsonian annual reports commenced in 1847, and being made to Congress, are published by that authority, and not at the expense of the Smithson fund. The earlier reports of the Secretary were printed in small pamphlet editions, but were collected and reprinted with the report for 1853, and with this the series of bound volumes may be said to have begun. The number, or edition, ordered by Congress has varied from year to year, but the proportion of copies placed at the disposal of the Institution has been distributed to its correspondents as fully and liberally as possible.

Smithsonian Contributions to Knowledge published in 1878.—For several years past the Institution has had in its archives a paper by the late Prof. Henry J. Clark, relating to the Lucernariæ, an extremely interesting group of marine animals closely allied to the *Acalephs*, or Jelly-fish. The death of the author before the work could go to press, and the difficulty of finding any one willing to undertake the editing of it, prevented immediate action on the memoir; but Prof. A. E. Verrill having agreed to take charge of the work, it was at length put to press, and was finally published in 1878. The memoir consists of 138 quarto pages and eleven plates, and it has been distributed to the leading zoologists. The Institution is under great obligations to Professor Verrill for the careful and critical supervision of the typographical execution of the work, as well as for some important notes and rectifications. Mr. Samuel F. Clark, of Johns Hopkins University, is also entitled to the thanks of the Institution for assistance in revising proofs during the period when Professor Verrill was ill.

The second quarto memoir, published in 1878, is a paper by Mr. William H. Dall, "On the Remains of later Prehistoric Man, obtained from caves in the Catherina Archipelago, Alaska Territory, and especially from the caves of the Aleutian Islands." In the Secretary's report for 1875 (page 48) will be found a brief notice of some interesting mummified human remains from the Aleutian Islands presented by the Alaska Commercial Company. These comprised a series of nine mummies from Kagaymil Island and one from Prince William's Sound. Mr. Dall's memoir on the subject has been printed, containing the result of a careful examination of these remains and the relics found with them, an account of the tradition and history relating to them, and such explanations of the manufacture, character, and use of the various associated articles as the author's observations during eight years in that region enabled him to furnish. Ten heliotype illustrations accompany the memoir, which, though inferior to finely engraved views in an artistic point of view, offer a style better suited to convey a correct idea of the complicated details represented than any other mode of illustration at present in use.

Two remaining quarto papers now in press will be published early in the year 1879. The first of these is the memoir of Dr. S. Habel, describing "The Sculptures of Santa Lucia Cosumalwhuapa, in Guatemala." As this interesting work was quite fully described in the Secretary's last Report (for 1877, pages 13 to 16), it is unnecessary here to particularize it further.

The other paper referred to (constituting the fourth of the above-mentioned series) is "A Classification and Synopsis of the Trochilidæ," by Mr. D. G. Elliot. The beautiful and brilliant-colored "metallic" plumage of the humming-birds in many instances assumes, among individuals of the same species, widely-contrasted hues, rendering the correct identification of the species by the naturalist only possible through a considerable experience or the opportunity of examining a large series of specimens. Within the past ten years a large number of new species have been discovered in this group, supplying important links between previously-known species that could not have been heretofore harmoniously ranged in the family. The vast collection which has produced the material for this work contains many types and specimens of great rarity, obtained from such well-known trochilidists as Bourcier, Gould, Verreaux, &c. Of the 426 species acknowledged in the work as worthy of such rank, 380 are contained in the author's collection, represented by about 1,800 specimens. A novel feature of the work is the engraving that accompanies the diagnosis of each genus, illustrating the characteristics by which any specimen may be readily referred to its proper genus. The characters recognized as most important for determining a system of classification are taken from the male bird alone, it being found impossible to harmonize in so large a group any that should be selected from the two sexes indiscriminately. The present synopsis will be useful both to the student and to the naturalist by enabling them to easily identify their specimens, and will assist them to a natural classification of the family.

Miscellaneous Collections published in 1878.—Among the "Collections" published in the past year have been several very important circulars intended to facilitate the collection of material for scientific research. The first of these, prepared by Prof. O. T. Mason, at the request of the Institution, relates to the various remains of American archæology scattered throughout different parts of our continent, consisting of mounds, earthworks, ditches, graves, &c. A vast amount of isolated and disconnected research has been directed toward these objects, in most cases by persons ignorant of the true method of examination or of the precise nature of the problems to be solved in connection with them. The circular referred to comprises 15 pages, indicating the features of special interest, a record of which it is desired to possess, and giving a table of symbols to be used to secure uniformity of illustration and facility of reference. It also invites contributions of notes, surveys, maps, illustrations, &c., of the objects, and also requests the contribution of such specimens as may be found in the localities described, including stone implements, pottery, bone tools, &c. Of this circular many thousand copies have been distributed, and these have elicited a vast amount of material. This is all carefully and systematically classified and arranged, and as soon as it appears to be measurably complete it will be placed in the hands of one or more specialists, by the aid of whom it is hoped the Institution may be able to prepare an exhaustive treatise on the subject which will mark as important a stage of progress in the history of American archæology as was done by its publication, in 1849, of Squier & Davis's work upon the ancient mounds of the Mississippi Valley.

The second circular published was one prepared by P. R. Uhler, of Baltimore, in reference to the collection of specimens of *craw-fishes*. This group of fresh-water crustaceans, which is found in most parts of the world, with some curious exceptions, furnishes an interesting field for inquiry into the modifications produced in animal forms by certain physical or other conditions, Professor Huxley, among others, having lately prepared an elaborate paper upon the subject. In previous years quite a number of new craw-fishes were described from the collections of the National Museum, by Mr. Charles Girard. The group was afterwards made the subject of a very comprehensive investigation by Dr. H. Hagen, of Cambridge. It is, however, thought that there is room for still further inquiry, and the material in possession of the Smithsonian Institution will be placed in the hands of competent specialists for investigation. In the circular an illustration of the craw-fish is given, for which the Institution is indebted to Messrs. Appleton & Co., New York.

The third circular, to form part of a forthcoming volume of Smithsonian Miscellaneous Collections, is in reference to the living *reptiles* of

North America. The United States Fish Commission, under the auspices of the Smithsonian Institution, exhibited at the Philadelphia Centennial of 1876 an extremely interesting series of plaster and papier maché casts of fishes, cetaceans, and some reptiles, all carefully colored from nature, and representing a much larger number of such objects than had ever been brought together under one roof. Since that time the artists connected with the National Museum have been diligently engaged in extending and improving the series, and for nearly two years past their efforts have been conducted especially in the line of the reptiles. The circular in question was intended to indicate precisely the forms or species desired, and it has been extensively distributed. As the result, the Institution was the recipient, in 1878, of very large numbers of living turtles, serpents, lizards, salamanders, &c., the greater portion of which has been carefully molded and reproduced in artistic style. It is believed that no museum extant can show such a series of serpents, in their natural attitudes, as is now on exhibition in the National Museum.

Another publication of 1878 is a new "List of Foreign Correspondents." The rapid increase in the number of scientific establishments in relationship with the Institution requires a new edition of this list every few years; and although the present one is much more extensive than that published in 1872 (containing 2333 numbers of titles as compared with 1919), even now arrangements are being made by the Institution for a still more complete and exhaustive edition. With this view a circular has been sent to all the names upon the present list, asking for rectifications or typographic corrections, and the addition of any addresses of public libraries, learned societies, or scientific bureaus of governments not already included. The Institution also requested secretaries of societies to furnish a list of the names and addresses of persons actively engaged in scientific or literary investigations in their respective towns, together with the particular branches of learning to which each was devoted, with the view of facilitating communication and exchanges with *specialists* in all parts of the world. The responses to these requests are coming in rapidly; and when all are received, a suitable arrangement and publication of the material will be made.

Twenty years ago (in 1858), the Institution published a list of the *Diptera* (flies, musquitoes, &c.) of North America, by Baron R. Osten-Sacken, at that time attached to the Russian Legation at Washington. The author, although especially a student of the order of diptera, was interested in other groups, and coming to the United States at a time when our entomologists were few and widely scattered, he devoted a considerable part of his leisure to travel over the country, making the personal acquaintance of most of those interested in this branch of natural history. In that connection he rendered a valuable aid to the extension of American entomologic science, which is entitled to public recognition. Through his efforts numerous entomologists, situated far apart, and prosecuting studies of a similar character, without the knowledge of other labors than their own, were brought into relations of correspondence and exchange, and thus, by their mutual sympathy and support, and by the concentration of effort on the part of each to some special line of research, the common interest of science was advanced. We regret to say that after many years sojourn in this country, Baron Osten-Sacken has returned to Europe, where, however, his assistance is continually invoked by entomologists desiring information in regard to type specimens, books not procurable in the United States, &c.

The list of *Diptera* aforesaid (published in the Miscellaneous Collections) brought together a mass of references to the descriptions of about 1,800 species, scattered in more than one hundred different works and scientific papers. Such a publication was an indispensable preliminary step before any study of the diptera could be attempted. This formed the first of a series of works undertaken by the Institution to facilitate the study of entomology, which has included diptera, coleoptera, lepidoptera, neuroptera, and hymenoptera.

During the past year the work of Baron Osten-Sacken, much extended by his later critical studies, has been republished by the Institution. This new edition of the work is not merely a revision of the catalogue published twenty years ago; but it is an entirely new one prepared on a different plan. The difference between *eleven* and *sixty-six*, the number of species of one genus, *Trypeta*, represents the addition made to our knowledge during the interval between the two catalogues. Other genera give similar results. Another important difference between the old and new catalogues consists in the fact that the majority of the species enumerated in the latter are represented in a collection now in the Museum of Comparative Zoology in Cambridge, Mass., which contains over 2,000 named and described species of diptera from North America. The region embraced in the present catalogue is the whole of North America, including the West Indies. It has been the effort of the author to make sure that every name in the list should actually represent a different species. To attain this result, he visited and examined the museums in London, Paris, Lille, Berlin, Frankfort, Darmstadt, Turin, and Vienna. Of all orders of insects the diptera offer probably the most difficulties to the describer, arising from the minuteness of the characters on which generic and specific distinction are based. Each family requires a special study, and a dipterologist may be very well versed in some families, without being able to express any opinion with regard to questions concerning others. In the introduction to the catalogue, the author presents some recommendations as to the best course to be pursued in the study of diptera, and advises *specialization*. Amateurs may collect and name specimens, but should not publish anything until they have chosen some single family and nearly exhausted it by study and collecting. "The exhaustive study of a single family is far more remunerative both in pleasure and in usefulness than the random description of numerous new species." The catalogue forms an octavo volume of 324 pages, and includes a full index.

Another paper published in 1878, to be mentioned, is a "Botanical Index," prepared by Prof. Sereno Watson, of Cambridge, Mass. The purpose of this index is to furnish references to whatever has been published respecting the plants of North America, under their Linnean specific names, in works or papers that may be classed as belonging to systematic botany. For the region west of the Mississippi and for British America, the literature of which is almost wholly fragmentary and greatly scattered, and on account of which especially the work was originally begun, it is intended to be complete. And it is essentially so also for the eastern flora, where, however, there is not the same necessity that the citations should be exhaustive. To avoid the perpetuation of errors it was desirable to eliminate false species and to correct wrong determinations wherever they had gone upon record. This could not have been thoroughly done without a complete revision of the flora itself, which was of course out of the question; nevertheless it was rendered to a considerable extent possible as respects the western flora, by the author's connection with the "Botany of California"; and in many other cases he was enabled to decide upon the validity of species, and to verify determinations or to settle doubtful synonymy by comparison of specimens themselves in the collection of the Harvard Herbarium.

The delays that have arisen in the preparation of the volume have not been without compensation in the far more complete and satisfactory results which were only thus made possible; and the deficiencies of the earlier portions are largely supplied by the copious appendix, which makes the whole essentially complete, up to the date of publication. The portion now printed covers the ground of Torrey and Gray's Flora of North America, which was published in 1838–1840, and is now so completely out of date as to leave this portion of our botany nearly as much in need of revision as any other. Until such revision can be made (and it must still be delayed some years), the "Index" will necessarily be a partial substitute—in some respects sufficient, inasmuch as it shows what genera and species are recognized as forming our flora, and also as concerns the synonymy, which could not be given with any such completeness, within the limits of the desired revision, and moreover sufficient in its references to all existing descriptions of those species. In any given case, these descriptions may indeed be practically inaccessible, or they may be incomplete or faulty, and it is herein that nothing can be a substitute for a "Flora," which shall bring together into one volume perfected descriptions, together with such grouping of genera and species as to indicate their natural affinities. For the preparation of such a Flora, or for the study of any special portion ot the field, the present Index will meantime be an important aid, giving as it were a skeletonized history of each individual species, and affording a clue to all that is known toward the needed filling out of the outline. The total number of orders given in the Index is 69; of genera, 545; of species, 3,038. The work forms an octavo volume of 484 pages.

A work too long delayed, and constituting a most important addition to the Miscellaneous Collections—a memoir of the founder, James Smithson, with a collection of his published contributions to science, followed by a documentary history of the organization, rise, and progress of the Institution—has during the past year been collected and prepared, and is now in press.

At a meeting of the Board of Regents, held January 23, 1878, it was resolved that the Secretary be requested to have a memoir of James Smithson prepared and published, to include all his scientific papers now accessible; and that the Secretary prepare and publish a history of the origin and progress of the Institution. In accordance with these resolutions, the Secretary directed Mr. William J. Rhees, the chief clerk, who had been connected with the Institution for more than twenty-five years, to commence the collection of material for these works, and on the death of Professor Henry, Mr. Rhees was requested to continue his labors. No compilation of this character having been previously attempted, the investigation involved a laborious research.

The scientific papers of Smithson, which originally appeared in the Philosophical Transactions of the Royal Society of London, and in Thomson's Annals of Philosophy, have been collected and reprinted; they occupy 120 octavo pages. These memoirs were submitted to several chemists and mineralogists for an estimate of the scientific value of Smithson's researches, and the present acceptance or recognition of the results obtained by him.

The history of the Institution contains the will of Smithson, the manner in which the bequest was obtained by the United States, the correspondence between Hon. Richard Rush, the special agent of this government, and the officials and attorneys in England, an account of the suit in chancery which was found necessary to obtain the fund, an account of the residuary legacy or sum left in England as the principal of an annuity to the mother of the nephew of Smithson, and how this was finally obtained and added to the fund. The legislation of Congress in reference to the bequest is given, including a reprint of every resolution, memorial, report, speech, and act from the proceedings of Congress that have any reference to the fund or to the establishment and objects of the Smithsonian Institution, from December 17, 1835, when President Jackson first informed Congress of the bequest, down to the 1st January, 1878.

The collection of this part of the history involved a minute examination of every page of the "Globe," containing the report of the proceedings of Congress, and also a large number of documents and many of the records printed and in manuscript on file at the Capitol or elsewhere. The various plans proposed in the Senate and House of Representatives for the carrying out the intentions of Smithson, by John Quincy Adams, Mr. Robbins, Mr. Choate, Mr. Marsh, Mr. Owen, and many others are given in full, and form an exceedingly interesting exhibit of the views of men in political life as to the best means of increasing and diffusing knowledge. This part also includes the history of the controversy in relation to the management of the Institution arising from the resignation of Mr. Choate from the Board of Regents, and the speeches of Senators Pearce, Mason, Douglas, Badger, and Clayton, and of Representatives English and Meacham, together with the reports of the Senate Judiciary Committee, and of a special committee of the House. As throwing light on much of Congressional action and to show the intense interest Mr. John Quincy Adams felt in the bequest, copious extracts are made from his diaries.

The volume also contains the various plans proposed for the organization of the Institution by scientific and literary men, including Mr. Rush, Dr. Wayland, Dr. Cooper, Dr. Chapin, with the report of the committee of organization of the Board of Regents; the programme presented by Professor Henry in December, 1847, and the opinions of this programme expressed by Dr. Beck, Professor Silliman, Dr. Gray, the American Academy of Arts and Sciences, the presidents of Columbia, Williams, Hamilton, Delaware, Pennsylvania, Georgetown, Amherst, Saint John's, Brown, Bowdoin, Charleston, Hampden Sidney, Madison, William and Mary, Cumberland, Alabama, Marietta, Tennessee, North Carolina, Trinity, and many other colleges and societies.

These articles will form parts of the Smithsonian Miscellaneous Collections, and will not only be of interest to the Regents and those immediately connected with the management of the Institution, but to all who wish to ascertain the views and acts of some of our most prominent men in relation to science for nearly half a century. The history of the Institution will show what difficulties surrounded its organization, the diversity of opinion as to its proper functions, the opposition to be overcome, and the value of the wide and comprehensive plans of the Secretary, Professor Henry, to whose clearness of conception, firmness of purpose, and purity of character the success of the Institution is mainly indebted. His views, though but little understood and appreciated at first, have steadily gained the favor of the scientific and literary world, and are now universally recognized as the best adapted to accomplish the great purpose of Smithson.

Bulletins of the National Museum.—In the Secretary's Report for 1875 (page 14) it was stated that, during the past year another series of publications, which would form a part of the Miscellaneous Collections, had been commenced under the above title. This series is intended to illustrate the collections of natural history and ethnology belonging to the United States, and constituting the stock of the National Museum, of which the Smithsonian Institution is the custodian. These bulletins, prepared at the request and mainly by the attachés of the institution, have been printed under the authority of the Secretary of the Interior. They form an independent series, which has proved very acceptable to naturalists, as enabling them to obtain prompt information as to the additions to and the components of the National Museum.

The following is a list of the Bulletins already published:

No. 1. Check-list of North American Batrachia and Reptilia; by Edward D. Cope. 1875. 106 pp.

No. 2. Contributions to the Natural History of Kerguelen Island; by J. H. Kidder, M. D.; Part I, Ornithology; edited by Elliott Coues. 1875. 61 pp.

No. 3. Contributions to the Natural History of Kerguelen Island; Part II, Oölogy, Botany, Geology, Mammals, Fish, Mollusks, Insects, Crustaceans, Annelids, Echinoderms, Anthozoa; by Kidder, Coues, Gray, Endlich, Gill, Dall, Osten-Sacken, Hagen, S. J. Smith, Verrill, and S. F. Clark. 1876. 122 pp.

No. 4. Birds of Southwestern Mexico; collected by Francis E. Sumichrast. By George N. Lawrence. 1876. 56 pp.

No. 5. Catalogue of the Fishes of the Bermudas; by G. Brown Goode. 1876. 82 pp.

No. 6. Classification of the collection to illustrate the Animal Resources of the United States; by G. Brown Goode. 1876. 139 pp.

No. 7. Contributions to the Natural History of the Hawaiian and Fanning Islands, and Lower California; by Thomas H. Streets, M. D. 1877. 172 pp.

No. 8. Index to the names which have been applied to the subdivisions of the class Brachiopoda previous to the year 1877; by William H. Dall. 1877. 88 pp.

No. 9. Contributions to North American Ichthyology; Part I; Review of Rafinesque's Memoirs on North American Fishes; by David S. Jordan. 1877. 53 pp.

No. 10. Contributions to North American Ichthyology; Part II; Cottidæ, Etheostomatidæ, Percidæ, Centrarchidæ, Aphododeridæ, Dorysomatidæ, Cyprinidæ, Siluridæ. By D. S. Jordan. 1878. 120 pp., with 45 plates.

No. 11. Not yet published.

No. 12. Contributions to North American Ichthyology; Part III; by D. S. Jordan and A. W. Brayton. 1878. 237 pp.

Of the above, those published during the past year are the Bulletins numbered 10 and 12. The former comprises the second part of Prof. David S. Jordan's Contributions to North American Ichthyology, and includes notes on Cottidæ, Etheostomatidæ, Percidæ, Centrarchidæ, Aphododeridæ, Dorysomatidæ, and Cyprinidæ, with revisions of the genera and descriptions of new or little known species; and Synopsis of the Siluridæ of the fresh waters of North America, with a bibliography of all the genera and species. It forms an octavo pamphlet of 120 pages, with 45 plates.

The latter (No. 12) comprises the third part of Contributions to North American Ichthyology, including the distribution of the fishes of the Allegheny region of South Carolina, Georgia, and Tennessee, with descriptions of new or little known species; by David S. Jordan and Alembert W. Brayton. This paper is based primarily on the collections made by the authors and a party of students of Butler University, Ohio, during the summer of 1877, in various streams in the Southern States, classified under the following basins: 1, Santee; 2, Savannah; 3, Altamaha; 4, Chattahoochie; 5, Alabama; 6, Tennessee; 7, Cumberland. In the course of the investigations detailed in this paper some light has been thrown on the laws which govern the distribution of fresh-water fishes in general. A synopsis is also given of the family Catostomidæ; by David S. Jordan, and a bibliography is given of all the known works on Catostomidæ.

Proceedings of the National Museum.—In imitation of the practice of those learned societies which publish periodically descriptions of new species, &c., in the form of proceedings of weekly or monthly meetings, and thus present to the world the discoveries connected with the establishment at the earliest practicable moment, it appeared to be very desirable that the National Museum should have some medium of prompt publication for announcing descriptions of specimens received (many of which are new species), as well as other interesting facts relative to natural history furnished by the correspondents of the Institution. To meet this want, an order was obtained from the honorable Secretary of the Interior, authorizing the publication of a volume of "Proceedings of the National Museum" for the year 1878, not to exceed 500 pages.

The publication of the "Proceedings of the National Museum" has accordingly been commenced, the work comprising short descriptions of the additions to the Museum, and accounts of new species, or illustrations of species collected in particular regions of country. It is printed in successive signatures, as fast as copy sufficient for 16 pages is prepared, each signature having printed at the bottom of its first page the date of actual issue, for settling any questions as to priority of publication. It is at once distributed to scientific societies and leading naturalists in this country and in Europe. A large number of important articles of greater or less length have already been printed, to form the volume for 1878, now nearly completed. They consist of articles on new species of fishes collected by the United States Fish Commission; papers on the birds of the West Indies, collected under the auspices of the Smithsonian Institution, &c. Of this series, about 250 pages have been printed during the year 1878, being produced (as in the case of "Bulletins") at the expense of the Interior Department, by which all the disbursements connected with the service of the National Museum are made.

Reports of the United States Fish Commission.—A series of publications which may be considered as in some respects connected with the work of the Institution not only in the *personnel*, but in the subjects of natural history discussed and in the resulting contributions to our knowledge may properly be here noticed. The present Secretary being at the head of the United States Commission of Fish and Fisheries, and the work accomplished by this agency in increasing and diffusing scientific as well as practical information being quite within the objects and province of the Institution, much of the material would legitimately form a portion of the Smithsonian Contributions or Miscellaneous Collections. These reports are, however, published by the government, and are distributed by Congress.

Four volumes of this series have been published, each being of octavo size and comprising about 1,000 pages. The last of these reports, published in 1878, contains 1,089 pages, and embraces: (A) General considerations on the progress of operations; (B) Inquiry into the decrease of the food-fishes; (C) The propagation of food-fishes, as the shad, the salmon, the white-fish, and the carp; (D) Tables showing the distribution of shad, salmon, &c., the places, dates, and quantities hatched by the United States Fish Commission from 1872 to 1876. The Appendix contains a number of important papers, the most elaborate of which is a history of the American whale fishery, by Capt. Alexander Starbuck. This is followed by one on the carp and its culture, by Rudolph Hessel.

Smithsonian annual report.—The Annual Report of the Institution for 1877 was transmitted to Congress on the 6th of February, 1878, and 10,500 extra copies of it were ordered to be printed, 1,000 for the use of the Senate, 3,000 for the House of Representatives, and 6,500 for the Institution. It forms an octavo volume of 500 pages, with 49 wood-cut illustrations. The principal articles in the Appendix are a list of the more important explorations and expeditions, the collections of which have constituted the main sources of supply for the National Museum from 1850 (and even earlier) to 1877; a translation of Holmgren's memoir on color-blindness, in connection with which is reprinted an article on the same subject by Professor Henry, published in 1845; translations of the reports of the transactions of the Geneva Society of Physics and Natural History for 1875, 1876, and 1877, of Weisman's article on the change of the Mexican Axolotl to an Amblystoma, and of short memoirs on meteorological subjects, by Hann, Reye, Sohncke, Colding, and Peslin; notes on the history and climate of New Mexico, by Thomas McParlin, and brief articles on ethnological topics, by C. Rau, George L. Cannon, Moses Strong, J. N. de Hart, E. E. Breed, M. W. Moulton, Mrs. Gilbert Knapp, W. H. R. Lykins, James Shaw, J. Cochrane, George W. Hill, H. B. Case, F. Miller, Joseph Friel, W. M. Clark, Charles C. Jones, jr., W. B. F. Bailey, A. S. Gaines, K. M. Cunningham, S. S. Haldeman, A. M. Harrison, S. P. Mayberry, William M. Taylor, Edwin M. Shepard, George J. Gibbs, F. L. Galt, and Stephen Bowers.

ANTHROPOLOGY.

As in previous years, the subject of the anthropology of North America received special attention from the Institution. Its earliest publication, constituting the first volume of the "Smithsonian Contributions to Knowledge," was the work of Squier and Davis on the ancient monuments of the Mississippi Valley; and to this the inquiries of the past third of a century into the early history of man in the Northwest owe their chief impetus. The book is a universal guide, and is even now a standard. The edition at the command of the Institution has long since been exhausted, and it has been proposed to republish it to meet the urgent calls of the public. Unfortunately, the destruction of the wood-cuts by the fire of 1865 would render the cost of reproducing them so great as to make it doubtful whether it would not be better to use the money that would be needed for it in the preparation of a more extended work on the same subject, which has been in contemplation by the Institution for several years past.

In the list of publications of the year is mentioned an archæological circular, prepared by Professor Mason, and distributed in very large numbers. The object of this has been to secure information of the minutest details in reference to the construction of mounds, earthworks, and other traces of aboriginal engineering, as well as of articles of every description and character found in the mounds, in the graves, and in the superficial soil.

The answers to this circular have been unexpectedly abundant and varied, and a great mass of material is now in the possession of the Institution and in process of elaboration. The papers in relation to the mounds, earth-works, &c., are placed in the hands of Professor Mason, of Columbian University, for critical investigation and examination; and under his editorship they will be arranged and ultimately printed, together with numerous illustrations which accompany them. A series of maps will also be completed, containing information obtained from these and other sources, so that we shall have some satisfactory idea of their geographical distribution, extent, &c., throughout the country.

The investigation of the aboriginal relics is in charge of Prof. Charles Rau, the superintendent of the archæological department of the National Museum. As preliminary to a systematic work in this direction Prof. Rau has lately completed the rearrangement of the archæological collections of the Museum, carefully eliminating the duplicates, but retaining whatever may serve to illustrate the geographical distribution of forms and material, or the variation in pattern. Under his direction, also, numerous drawings have been made on wood and partially engraved.

A detailed statement of the donations to the National Museum relating to this branch of science will be found in the list of Contributors to the Museum, and also in the general account given subsequently, of the several additions to the Museum. It may, however, be well to call special attention to two northern collections in this department; one received from Mr. E. W. Nelson, a signal-station observer at Saint Michaels, in Alaska; the other from Mr. L. Kumlien, the naturalist of the Howgate expedition to Arctic America. These illustrate very fully the nature and character of art among the Esquimaux on both sides of the continent, and with what has been heretofore obtained from the same region, as also the coast of Arctic America, through the agency of Mr. R. R. McFarlane, render this series the most complete of its kind in existence.

Special acknowledgment is due to the American Express Company, through Jas. C. Fargo, esq., general superintendent, for giving instructions to all the agents of the company to co-operate with the Institution in the collection of archæological material for the Museum.

METEOROLOGY.

Among the first objects of consideration by Professor Henry, after the commencement of active operations on the part of the Smithsonian Institution, was that of meteorology, and for more than twenty-five years it has received a large proportion of his own attention and consideration, as well as the aid of the Institution as far as its means would permit. Prior to the period named more or less attention had been paid to the subject, and efforts had been made to secure an extensive and continuous series of observations. These, for the most part, however, were limited to single places, and more rarely extended to counties or States; and it is to Professor Henry that we owe the establishment of a uniform system over an entire continent. Little by little the work was extended until, at the time of its fullest activity, it had its agents in nearly every county of most of the States of the Union; indeed, throughout the whole of British North America, and even in the remotest post of the Hudson's Bay Company, in Mexico and Central America, the services of observers were utilized. Some of these were provided with full sets of meteorological apparatus, so that observations could be made with the utmost precision; others had only a thermometer and barometer, while still others had nothing but a thermometer.

Several different series of blanks were distributed by the Institution corresponding to the different classes. The blanks were returned monthly and duly filed. In the earlier part of the work some instruments were furnished, such as barometers and thermometers. Subsequently, however, it was found that the expense was too great, and only occasionally were thermometers and rain-gauges supplied. There was, however, no lack of persons who were ready to take part in this system, and not only to give their time, but also to purchase their own instruments.

The interest of the observers was maintained by a constant correspondence with the Institution. Copies of the Smithsonian Reports and other publications were duly transmitted to them, and any inquiries or communications from them on scientific subjects were promptly responded to.

In this way a body of collaborators was secured to the Institution, whose services cannot be overestimated, since they not only furnished information relating to meteorology, but they were always ready to supply information and assistance in other directions. To that body of men the National Museum owes a very large part of the extensive and complete series of illustrations of North American natural history that gives to it so great a prominence, this being the result of successive applications for aid from particular classes. Thus, whenever the attention of the Institution was directed to the fact that some particular branch of natural history required its fostering care, circulars were prepared and issued to the meteorological correspondents, invoking co-operation, and asking them to collect objects of the kind that might be found in their neighborhood, so that, not only all North American species might be gathered, but accurate determinations made of their geographical distribution. Very extensive responses usually followed these appeals, and in many cases sufficient material was secured to place the subject on a permanent and satisfactory basis. The works of the Institution on many orders of insects and on fresh-water and land shells, reptiles, birds, mammals, &c., were all based more or less entirely on collections and information obtained by the Smithsonian observers.

As a result, therefore, of over twenty-five years' observations by such men, the mass of meteorological information obtained became very great, and even though a certain per cent. of the observations could not lay claim to that minute accuracy which is generally required, yet it was found that, for many purposes, such as the general indications of variations in temperature, barometrical pressure, rain-fall, &c., in the collation of all observations the errors disappeared, and an average was secured which did not differ essentially from what would have been derived from more accurate observations.

The results of these observations have been published by the Institution in several forms. During the time when the work was carried on partly by the assistance of the Department of Agriculture, the reports of that establishment contained the general results. In 1855, two quarto volumes were published at the expense of the government. Subsequently, however, a system of special digests was undertaken under the supervision of Professor Coffin, for the winds; and of the temperature, rainfall, &c., under Mr. Charles A. Schott, of the United States Coast Survey, a full account of which will be found in the former reports of the Institution.

A second edition of the work on the Winds of the Globe, commenced by Professor Coffin, and unfinished at his death, a few years ago, was completed under the auspices of his son, and published by the Institution. This is one of the most important treatises on meteorological science that has ever appeared from any press.

Shortly after being honored with the appointment as Secretary, I invited a committee, consisting of Mr. Charles A. Schott, Prof. Cleveland Abbé, and Mr. William Ferrel, to consider the subject of the unfinished meteorological work of the Institution, and to suggest a plan by which it could be carried on and completed, with due reference to the state of its finances. This committee met at the Institution and carefully considered the whole subject, with the manuscripts before them, and concluded that a new edition of the rain-fall tables should be completed as soon as possible, this being a subject of great interest, both theoretically and in its practical applications. An allowance was therefore made for the completion of this work, and it will be ready for the press during the present year. The publication of this new edition of the rain-fall tables will be commenced and completed as soon as practicable. The barometrical reductions, the digest of the periodical phenomena of animal and vegetable life, &c., will be prosecuted as rapidly as the funds of the Institution will warrant.

It is, of course, unnecessary to refer to the fact that active operations in regard to meteorological observations, in accordance with the policy of Professor Henry have been transferred to the Weather Bureau of the Signal Department of the United States Army, under the care of General A. J. Myer, and that hereafter the meteorological expenditures will be confined to completing the presentation of the results obtained during the twenty-five years of the active work of the Institution in that direction.

RESEARCHES.

The appropriation made to Dr. H. C. Wood, jr. in 1876 and 1877 for experiments to determine the nature and cause of the increased temperature of the body during fever has been expended and a report of the investigations is being prepared for publication by the Institution. A brief abstract of this memoir will be found in the appendix to this report.

The first point to be determined was whether fever was as complex as it appears, or whether there be not some dominant symptom characteristic of the process. By artificially heating living animals, generally and locally, it was found that elevation of the bodily temperature is sufficient to produce all the nervous and circulatory symptoms of fever and that the cooling of the heated part is capable of removing the symptoms, so that fever may be defined to be a morbid process which produces elevation of the bodily temperature.

The next point was to determine whether the increase of the bodily temperature in fever was due to an increase of the amount of heat produced, or to the failure of the body to throw off its heat. For this purpose the laws governing the production and loss of animal heat in health were studied by means of calorimetric and cardiometric observations on animals under various conditions, and it was determined that there is in the cortical region a nerve-center which controls the production of animal heat.

The subject of fever itself was then investigated. The experiments were mostly made upon dogs, each experiment continuing for from three to six days. Thermometrical readings were made every twenty minutes by night and by day, and the normal and febrile states were studied both when food was administered and when withheld. The result of this was to show that there are two sources of animal heat, one from the stored-up materials of the body, and the other from the food, the first being the one manifested in fever.

The results of the whole investigation are summed up in eleven conclusions which are given in the abstract referred to.

The publication of recent investigations of the motion of the moon* has rendered a re-discussion of the ancient solar eclipses desirable. This work has been commenced under the auspices of this Institution by Mr. D. P. Todd, M. A., Assistant Nautical Almanac Office. Hansen's tables of both the sun and moon are employed, the latter being corrected from the results of Professor Newcomb's researches. So far as the work has now progressed, the computations relate to seven eclipses—those of Thales, at Larissa, of Ennius, of Agathocles, at Stiklastad, and the two eclipses of the thirteenth century which have been discussed by Celoria, of Milan. The adopted value of the secular acceleration having been deduced from entirely independent data, it is hoped that this investigation will throw new light on the interpretation of the ancient eclipses, and point toward the true value of the secular acceleration which ought to be adopted in the construction of new tables of the moon. The progress of this investigation will be much facilitated by the new tables of eclipses,† now in press; and it is proposed to extend the original scope of the research to include a large number of supposed ancient ecliptic dates.

LABORATORY.

The original act of Congress calls for a laboratory as one of the elementary features of the Institution, and an establishment of this kind has always been maintained, with a greater or less degree of efficiency.

In consequence of the limited appropriations by Congress for the maintenance of the National Museum, it has for several years been impossible to secure the services of a mineralogist. Arrangements have been made, however, for such an officer; the laboratory has been put in thorough order; additional fittings have been introduced, necessary for its efficiency, and a complete stock of chemicals and other materials procured. It is now in proper condition for the prosecution of investigations requiring chemical and mechanical appliances.

The principal work of the laboratory at present is examining minerals sent to the Institution for that purpose from various parts of the country, very few days passing without the reception of one or more parcels, many of them from members of Congress, requiring consideration. The Institution does not undertake to make quantitative analyses, ex-

* Researches on the Motion of the Moon. By Simon Newcomb, Professor U. S. Navy. Washington Observations for 1875, Appendix II.

† Tables of Eclipses, from B. C. 700 to A. D. 2300. By Simon Newcomb, Superintendent Nautical Almanac. Washington, 1879.

cepting in behalf of the government, but is always ready to indicate the general composition of specimens sent for the purpose.

The laboratory will also be used in the identification of large quantities of crude mineral substances in charge of the Institution, to be classified preliminary to the selection of duplicates and their distribution to colleges and academies of the United States.

TELEGRAPHIC ANNOUNCEMENT OF ASTRONOMICAL DISCOVERIES.

As in previous years, the Institution has served as the medium for telegraphic communication between astronomers of the Old and New World, in regard to such astronomical discoveries as require prompt announcement, for the purpose of having all their phenomena investigated by concurrent action on both sides of the ocean. An accompanying list represents the announcements referred to and the dates at which they were respectively made. This feature of the work of the Institution is one of great importance, and is a very satisfactory demonstration of the extent to which its labors are prosecuted for the world in general, and not merely for a restricted portion of the United States.

The following is a list of the minor planets discovered in 1878:

No.	Name.	Date.	Discoverer.	Discoverer's No.	Observatory.
180	Garumna	January 29	Perrotin	5th.	Toulouse.
181	Eucharis	February 2	Cottenot	1st.	Paris.
182	Elsbeth	February 7	Palisa	12th.	Pola.
183	Istria	February 8	....do	13th.	Do.
184	Deiopeia	February 28	....do	14th.	Do.
185	Eunike	March 1	Peters	28th.	Clinton.
186	Celuta	April 6	Pr. Henry	?	Paris.
187	Lamberta	April 11	Coggia	2d.	Marseilles.
188	Menippe	June 18	Peters	29th.	Clinton.
189	Phthia	September 9	....do	30th.	Do.
190	Ismene	September 22	....do	31st.	Do.
191	Kolga	September 30	....do	32d.	Do.

The comets of 1878 have been—

Comet I, discovered July 7, by Lewis Swift, of Rochester, N. Y. This comet was observed in America by Dr. C. H. F. Peters only, the majority of American observers being in the West on eclipse expeditions. It is probably identical with a comet discovered by P. Ferrari at Rome in July. On July 20, Tempel's periodic comet was found by Winnecke, quite away from its ephemeris place.

Encke's comet was found on August 3 by Mr. Tebbutt, of Windsor, N. S. W.

CORRESPONDENCE.

Mention has been made by my lamented predecessor on several occasions of the general character of the correspondence of the Institution, and of its increasing extent. As might naturally be expected, this is now greater than ever before.

During the past year the number of letters received and sent out exceeded that for any previous corresponding period in the history of the establishment, the latter covering about 8,000 pages of press copy books. This increase was largely due—

(1) To renewed activity in the department of exchanges;

(2) To the execution of a comprehensive plan for extending the archæological cabinet of the Institution; and

(3) To the acknowledgment of letters of condolence on the death of the late Secretary.

As explanatory of the first of these sources of increase in the correspondence it may be stated that some months since a systematic effort was made looking to the early completion of as many as possible of the series of publications of foreign societies in the Smithsonian library, and, reciprocally, to supplying deficiencies in the numerous series of Smithsonian publications held abroad. To this end a communication was addressed to each of the nearly 3,000 foreign establishments in correspondence with this Institution, mentioning the volumes or parts of their respective transactions not at the time in possession of the Institution, and requesting that these be supplied; one of the conditions of a favorable response being a promise that the Smithsonian Institution would, in turn, fill whatever gaps it could in its own series. The responses, as was expected, were very prompt and most gratifying. Resulting therefrom, the Smithsonian library—now constituting the science library of the government—has been enriched by the addition of hundreds of valuable works of a character not usually obtained even by purchase, while the Institution itself has been brought into closer and more active relations than ever with its foreign correspondents of both hemispheres.

Regarding the second source of increase in the correspondence, it may be remarked that more recently a wide-spread distribution has been made of a circular relative to archæology. Indeed, it is hardly too much to say that this circular has been scattered broadcast over the land. Not only was it distributed to organized establishments of a literary, educational, and scientific character, to newspapers, postmasters, and, by generous permission of express companies, through their agents to individuals who might be known to them as specially interested in the subject, but a copy was systematically mailed with each *written* communication sent out by the Institution, no matter what the subject. This circular has proved more prolific of correspondence than was anticipated by its most sanguine friends. Inquiry soon followed inquiry for more detailed information as to desiderata in the way of specimens and information; requests were continuous to know if this or that article would be welcome; offers to lend objects for copying were numerous from individuals possessing unique and choice specimens, valuable to them only as heirlooms or curiosities, but who, while easily convinced of the little value of isolated collections in comparison with the importance to science of one grand, complete series, could not be persuaded to part with their archæological treasures; now and then private cabinets of more than ordinary character and extent have been brought to light; and, finally, modern "manufactories" of relics have been detected, and in this way forgeries, to some extent, driven from the market. Thus an extra amount of correspondence has been entailed that has proved no inconsiderable addition to the previous arduous labors of the officers of the Institution.

As the result, the Institution has received hundreds of specimens from all parts of North America as gifts, while by making copies in plaster or metal it has added to its cabinet many forms that would otherwise be unknown and inaccessible to the student as well as to the public at large. Many of these objects have proved of great archæological interest, and while not a few of them are almost indispensable for comparative study, all are more or less valuable in the elucidation of questions relating to the geographical distribution of aboriginal remains in the United States, and for filling gaps in State series. Moreover, by soliciting illustrations and descriptions of the rarer or more curious forms in private cabinets, the Institution has been saved much expense for transportation, its archæological experts rarely finding recourse to the original specimen necessary in determining what is or is not a desideratum.

As in previous years, the Institution was the recipient in 1878 of a large number of communications, having as a principal object the overturning of theories established by Newton and others, which, founded on experiment and observation, have long since been accepted as true by the scientific world. These, as is usual with papers of this class, while purporting to furnish the only rational explanation of the phenomena to be accounted for, generally displayed a degree of assumption entirely out of keeping with the spirit of true science; and while it would not be a work of much moment to prove to the unprejudiced, who may be acquainted with the subjects of such essays, that the propositions enunciated are wholly at variance with the fundamental and generally accepted principles of science, it is always exceedingly difficult to convince the authors of these "new doctrines" that they are not in accord with the scientific world. It would sometimes appear either that they are incapable of receiving the truth, or that, convinced of the fallacy of their reasoning, they prefer to cling to a false notion of originality rather than confess their error. Such communications, never brief, have, from time to time, been simply reiterations of previous expressions. "Correspondence with this class" of writers, as has been most truly observed by the late Secretary, is, indeed, "not only very onerous but difficult to manage, inasmuch as the rejection of their propositions is generally attributed to prejudice."

Another class of communications of a more intelligent character was also received during the past year, relating to subjects in physics and chemistry. In accordance with the custom of the establishment, these were submitted to gentlemen eminent in the several sciences to which they pertained, who for many years have cheerfully acted as collaborators of the Institution.

Although the Smithsonian system of meteorology was several years ago transferred to the United States Signal Office, communications continue to be received on practical questions connected with this subject. These with few exceptions have been referred to General Myer, and their authors so informed.

But increase in the correspondence of the Institution is by no means wholly attributable to the sources above mentioned. As the character of the establishment has become more widely known from year to year, the number of applications for information in the line of natural history has annually increased, particularly in botany, zoology, and mineralogy. In the last branch, supposed discoveries of mineral wealth are frequently made known to the Institution, and the specimens forwarded for examination—which is always gratuitous. The determination of their character, however, seldom requires more than a *qualitative* analysis, and in the great majority of instances the specimens are found to be of no commercial value.

EXCHANGES.

There is, perhaps, no one feature of the Smithsonian Institution by which its mission for the diffusion of knowledge, if not its increase, is more thoroughly accomplished than by its extended system of international exchanges. This began in the earliest days of the Institution, from the necessity of making some suitable arrangement by which its publications might be promptly transmitted to the learned societies of America and the world, and corresponding works received in return. This required the organization of a thorough system, including special arrangements for transportation agencies in the various parts of the United States and of foreign countries; and as the machinery was sufficient to carry a larger amount of material than that belonging to the Institution itself, it was considered in strict accordance with the policy of the Institution to offer its services to other establishments.

Year by year the number of participators in the exchange was increased, and at the present date it is world-wide in its extent. With very few exceptions the institutions of learning, not only of the United States but of all America, carry on the greater portion of their scientific exchanges with the rest of the world through the Smithsonian Institution. Among the outside countries more especially to be mentioned are Canada, Mexico, Chile, Venezuela, &c.

The institutions are for the most part scientific societies publishing transactions, colleges and universities, State historical and agricultural societies, and technological institutions. All the departments of government in Washington, with few exceptions, also depend upon the same system for their foreign relationships. The system also includes the exchange of publications of special students in science.

For a long time the Smithsonian Institution carried on this work by the establishment of agencies through which its own transmissions were distributed to their destination, and from which all the returns were collected and forwarded to Washington. Of late years, however, in certain countries, these labors have been materially lightened by a portion of the exchange being undertaken by some learned society or by the government. These being constituted Smithsonian agents in their respective countries, receive whatever may be sent to them for distribution, collect the returns and transmit them, thus giving to the Institution the benefit of an intelligent superintendence of the work. The first of these organizations was that established some years ago by the University of Christiania, Norway; and by Holland in the patronage of the Scientific Bureau at Harlem, under the efficient supervision of Dr. E. H. Von Baumhauer. During the past year a similar organization has been effected for Belgium, and it is hoped that their number will continue to increase. Even now, without any formal arrangement to that effect, the Academies of Science of Stockholm, of Copenhagen, of Madrid, and of Milan discharge the services of agents of the Institution for their respective countries.

A still more recent movement has in contemplation the establishment of departments of exchange in all countries under the direction of their respective governments; and this is intended primarily to facilitate a mutual interchange of government documents, but is broad enough in its scope to include the publications of societies and of men of science. At present this arrangement has only been carried out formally for Belgium by the "Commission Belge d'Echanges internationaux," and for France by the "Commission Française des Echanges internationaux."

In the Appendix will be found the usual series of tables, showing, first, the number of parcels sent out by the Institution in behalf of establishments in North America; and, secondly, the packages received for the same parties. The total number of shipments of boxes, containing such transmissions, has not been quite so great in 1878 as in the year preceding. This was due to the interruption of the business caused by the death of Professor Henry, and in the desire, by the reorganization of departments, to give greater efficiency to that of the exchanges. On this account a large number of bundles have accumulated, which, however, will be distributed in the earlier months of the year; after which there will be no interruption to the usual routine of transmission.

Up to the present time the entire expense of this system of international exchanges has been borne by the Smithsonian Institution, beyond requiring that all outgoing parcels be delivered to the Institution free of expense. The enormous increase, however, in the number and bulk of the packages delivered to the Institution has made it necessary to charge a small amount on this class of transmissions, and under the authority of the board, a circular has been prepared and issued, making one of the conditions of receipt the payment of five cents per pound on the parcels. This is actually below the cost, as it includes the expense of wrapping, of boxing, of forwarding, and a share of the salary of employés and agents, and other incidentals. It is about the same rate as is charged by the express companies for freight in bulk from Washington to Chicago.

To facilitate the business connected with the system of the Smithsonian exchanges the following rules have been adopted:

1. Transmissions through the Smithsonian Institution for foreign countries to be confined exclusively to books, pamphlets, charts, and other printed matter, sent as DONATIONS or EXCHANGES, and not to include those procured by purchase. The Institution and its agents will not receive for any address apparatus and instruments, philosophical, medical, &c. (including microscopes), whether purchased or presented; nor specimens of natural history, except where special permission from the Institution has been obtained.

2. The Departments or Bureaus of the United States Government to pay the Smithsonian Institution five cents per pound on their packages, which includes all expense of boxing, shipping, and transportation.

3. A list of the addresses and a statement of contents of each sending to be mailed to the Smithsonian Institution at or before the time of transmission.

4. Packages to be legibly addressed and to be indorsed with the name of the sender and their contents.

5. Packages to be enveloped in stout paper, and securely pasted or tied with strong twine—never sealed with wax.

6. No package to a single address to exceed one-half of one cubic foot in bulk.

7. To have no inclosures of letters.

8. To be delivered to the Smithsonian Institution or its agents free of expense.

9. To contain a blank acknowledgment, to be signed and returned by the party addressed.

10. Should *returns* be desired, the fact is to be explicitly stated on or in the package.

Unless these conditions are complied with, the parcels cannot be forwarded by the Institution.

Statistics of exchanges sent during the last ten years.

	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.	1878.
Number of boxes..	112	121	108	179	196	131	208	323	397	309
Bulk in cubic feet	1, 033	1, 189	772	954	1, 476	933	1, 503	2, 261	2, 779	2, 160
Weight...........	23, 376	31, 383	28, 950	26, 850	44, 236	27, 990	45, 300	80, 750	99, 250	69, 220

The following table exhibits the number of foreign establishments with which the Institution is at present in correspondence, or, in other words, to which it sends publications and from which it receives others in return:

Foreign institutions in correspondence with the Smithsonian Institution.

Algeria	6	Iceland	4
Argentine Republic	14	India	30
Australia and Tasmania	32	Italy	187
Austro-Hungary	156	Japan	6
Belgium	112	Java	5
Bolivia	1	Liberia	1
Brazil	10	Mauritius	3
British America	20	Mexico	16
British Guiana	3	New Zealand	15
Cape Colony and St. Helena	7	Norway	25
Central America	2	Peru	4
Chili	8	Philippine Islands	3
China	1	Portugal	32
Colombia	3	Russia	162
Denmark	28	Sandwich Islands	2
Dutch Guiana	1	Spain	24
Ecuador	1	Sweden	22
Egypt	8	Switzerland	73
France	327	Turkey	12
Germany	507	Venezuela	2
Great Britain and Ireland	369	West Indies	8
Greece	8	International societies	7
Holland	66		
		Total	2,333

Special reference has been made in previous reports to the arrangement by which Congress places fifty copies of all the publications of the United States Government at the disposal of the Library Committee of Congress. These copies are to be exchanged, under its direction, through the Smithsonian Institution, for correspondingly complete series of the publications of such other governments as agree to the proposition. At present, the number of sets amounts to thirty-two, and includes the following governments. Of these, several came for the first time into the arrangement during the year 1878, and seventy-three boxes of the publications referred to, each box measuring seven cubic feet, have been distributed:

International exchange of government publications in 1878.

	Boxes		Boxes.
Argentine Republic	2	France	2
Bavaria	11	Germany	2
Belgium	2	Greece	2
Brazil	2	Hayti	2
Buenos Ayres	2	Holland	2
Canada (Ottawa)	2	Japan	2
Canada (Toronto)	2	Mexico	2
Chili	2	New South Wales	2
England	2	New Zealand	2

	Boxes.		Boxes.
Norway	2	Sweden	2
Portugal	2	Switzerland	2
Prussia	2	Tasmania	2
Queensland	2	Turkey	2
Saxony	2	Venezuela	2
Scotland	2	Victoria	2
South Australia	2		
Spain	2	Total	37

LIBRARY.

In accordance with the arrangement entered into shortly after the fire of 1865, between the Smithsonian Institution and the Congress of the United States, all the publications received by the Institution, in exchange or by donation, are transferred to the Library of Congress. The following enumeration represents the sum total of such increment:

Statement of the books, maps, and charts received by the Smithsonian Institution during the year 1878, *and transferred to the Library of Congress.*

Volumes:		
Octavo, or less	860	
Quarto, or larger	403	
		1,263
Parts of volumes:		
Octavo, or less	2,356	
Quarto, or larger	2,620	
		4,976
Pamphlets:		
Octavo, or less	1,953	
Quarto, or larger	463	
		2,416
Maps and charts		74
Total		8,729

Of course, as heretofore, the more important works, like the publications of the leading scientific and industrial societies and academies throughout the world, by their aggregations have continued to render the Smithsonian library one of the most valuable of the kind extant. It is believed that no collection elsewhere contains so large a number of volumes of scientific transactions and journals, or in so complete a series.

For the purpose, however, of perfecting the catalogue, it is proposed, in the early part of 1879, to print a list of what the Institution possesses of this character, inviting contributions of deficiencies and promising similar courtesy, so far as the publications of the Smithsonian Institution are concerned.

The following is a list of some of the principal works received by the Smithsonian Institution in 1878:

From the Ministry of Public Works, Commerce, and Industry, Lisbon: O Archivo Rural, vols. i–xv, Lisboa, 1858–1874, 4to. Memoria sobre a População e a Agricultura de Portugal, Lisboa, 1868, 8vo. Chimica Agricola, por J. I. F. Lapa, Lisboa, 1875, 8vo. Geographia e Estadistica Geral de Portugal e Colonias, por G. A. Perry, Lisboa, 1875, 8vo. Relatorio do Conselho Especial de Veterinaria, Lisboa, 1873, 4to. Manual de Viticultura pratica, por Visconde de Villa Major, Coimbra, 1875, 8vo. A Agricultura no Districto de Vizen, por J. B. Reis, Lisboa, 1871, 4to. Fomento da Povoação Rural em Hespana, por D. F. Caballero, Lisboa, 1872, 8vo. A Lombardia a Suisse e o Monte Rosa, por E. de Laveleye, Lisboa, 1871, 8vo. Recenseamento Geral dos Gados no Continente do Reino de Portugal en 1870, Lisboa, 1873, 4to and Atlas. A Vinha e o Vinho em 1872, por A. B. Reis, Lisboa, 1873, 8vo.

From the Society of Medical Sciences of Lisbon: Journal da Sociedade das Sciencias Medicas de Lisboa, 1836–1877, Lisboa, 8vo (54 vols).

From the Ministerio dos Negocias da Marinha e Ultramar, Direçcão Geral da Marinha, Lisboa: Bullarium Patronatus Portugalliæ, curante Vicecomite de Paiva Manso, vols. i–iii, and App., vol. i, Lisboa, 1868–1873, 4to (3 copies). Examen des Viagens do Doutor Livingstone, por José de Lacerda, Lisboa, 1867, 8vo (3 copies). Relatorios dos Governadores das Provincias Ultramarinhas, vols. i, ii, Lisboa, 1875, 4to (3 copies). Tratado de Hygiene Naval, por J. B. Fonssagrives, Lisboa, 1862, 8vo (3 copies). Descripção e Roteiro da Costa Occidental de Africa, por A. Magno de Castilho, vols. i, ii, Lisboa, 1866, 8vo (3 copies). Africa Occidental, vol. i, Lisboa, 1864, 8vo (3 copies). Regulamento para o Serviço de Sande Naval, Lisboa, 1871, 8vo (3 copies). Viagem da Corveta Dom João I a Capital do Japão no Anno de 1869, Lisboa, 1863, 8vo (3 copies). Historia Ecclesiastica Ultramarina pelo Visconde de Paiva Manso, vol. i, Africa Septentrional, Lisboa, 1872, 8vo (3 copies). Ensaios sobre á Estatistica das Possessões Portuguezas no Ultramar, vols. i–v, Lisboa, 1844–1862, 8vo (3 copies). Regulament para o Serviço de-Fazenda a Bordo dos Navias do Estado, Lisboa, 1875, 8vo (3 copies). Relatorio ácerca do Servico de Sande Publica, Lisboa, 1871, 8vo (3 copies). As Possessões Portuguezas na Oceania, por A. de Castro, Lisboa, 1867, (2 copies). Codigo Commercial de Signals para uso Internacional, Lisboa, 1868, 8vo (2 copies), &c., &c.

From the Australian Museum, Sydney: The Mammals of Australia, illustrated by Miss Harriett Scott and Mrs. Helena Forde. With a short account of all the species hitherto described. By Gerard Krefft. Sydney, 1871. Folio.

From the Hellenic Philological Society of Constantinople: Periodical Journal (Greek), vols. iv–viii, Constantinople, 1871–1874, small 4to. Homeric Theology, by George Konstantinidos (Greek), Constantinople, 1876, 8vo, Les Grecs de l'Empire Ottoman, par A. Synvet, Constantinople, 1878, 8vo.

From the Government of France: Direction Générale des Douanes.

Tableau général du Commerce de la France, avec les Colonies et les Puissances étrangères, 1869–1875, Paris, 1871–1876, 4to (7 vols.). Tableau général des Mouvements du Cabotage, 1869–1875, Paris, 1871–1876, 4to (7 vols.).

From the Medical Society of the State of New York, Albany: Transactions, 1807–1831, 1867–1870, 1873–1877. Albany. 8vo (9 vols.)

From the State Library of Pennsylvania, Harrisburg: Reports on Geology, Mineralogy, Oil-Wells, &c., &c. Harrisburg, 1876–1878. 8vo (21 vols.).

From the Library of the German Parliament, Berlin: Stenographische Berichte über die Verhandlungen des deutschen Reichstages. iii. sess., 1875–76, vols. i–iii; iv. sess., 1876, vols. i–iii; i. sess., 1877, vols. i–iii; Berlin, 1876–1877, 4to. Reichs-Gesetzblatt, 1875–1876, Berlin, 4to.

From the University of Chile, Santiago: Anales de la Universidad de Chile, 1875–1876 (4 vols.), Santiago, 8vo. Memoria del Interior, 1876, vols. i–ii, Santiago, 8vo. Memoria de Relaciones Esteriores, 1876, Santiago, 8vo. Memoria de Justicia, Culto, &c., 1876, Santiago, 8vo. Memoria de Hacienda, 1876, Santiago, 8vo. Memoria de Guerra y Marina, 1876, Santiago, 8vo. Sesiones del Congreso National de Chile, 1875 (4 vols.), Santiago, 4to. Anuario Estadistico de Chile, vol. xvii, Santiago, 1876, 4to. Anuario Hidrografico de la Marina de Chile, año ii–iii, Santiago, 1876–1877, 8vo. Quinto Censo Jeneral de la Poblacion de Chile, 1875, Valparaiso, 1876, 4to. Coleccion de Tratados celebrados por la República de Chile con los Estados estranjeros, tomo ii, Santiago, 1875, 4to. La Chili tel qu'il est, par E. Seve, tome i, Valparaiso, 1876, 8vo. Historia de Chile, 1831–1871, por Don R. S. Valdes, tomo i, Santiago, 1876, 8vo. La Cronica de 1810, por M. L. Amunátegui, tomo ii, Santiago, 1876, 8vo. Ensaye sobre los depósitos metaliferos de Chile, por Don I. Domeyko, Santiago, 1876, 8vo.

From the Royal Academy of Sciences, Lisbon: Memorias da Academia, Nova Serie, tomo iv, v, parte i, Lisboa, 1872–1877, 4to. Decada 13 da Historia da India, i, ii, Lisboa, 1876, 4to. Portugalliæ Monumenta, 2 parts, Lisboa, 1873, folio. Subsidios para a Historia da India Portugueza, tomo v, Lisboa, 1868, 4to. Corpo Diplomatico Portugueza, tomo v, Lisboa, 1874, 4to. Quadro Elementar dus Relaões politicas e diplomaticas de Portugal, vols. xii and xiii, Lisboa, 1874, 1876, 8vo. Flora Cochinchinensis, vols. i, ii, Lisboa, 1790, 4to. Historia dos Estabelecimentos scientificos e areisticos de Portugal, toms iii, vi, Lisbon, 1873–1876, 8vo. Jornal de Sciences Mathematicas, toms iv, v, Lisboa, 1873, 1876, 8vo. Tratado Elementar de Optica, Lisboa, 1874, 8vo. Historia de Congo, Lisboa, 1877, 8vo. Carro de Meteorologia, Lisboa, 1869, 8vo. Chimica Agricola, Lisboa, 1875, 8vo.

From the British Government: Facsimiles of National Manuscripts of Scotland, selected under the direction of the Right Hon. Sir William Gibson-Craig, Bart., lord clerk register of Scotland, and photozincographed by command of Her Majesty Queen Victoria by Colonel Sir Henry James, part iii, Edinburgh, 1872, folio.

From the Royal Library, Stockholm: Government Documents, 1877, 1878, Stockholm, 17 vols. and 8 parts, 4to.

From the Government of South Australia, Adelaide: Acts and Ordinances of the Province of South Australia, 1837–1835, Adelaide, 4to (6 vols.). Proceedings of the Parliament of South Australia, 1857–'8, i, ii; 1858, i, ii; 1859, i, ii; 1860, i–iii; 1861, i–iii; 1862, i–iii; 1863, i; 1864, i–iii; 1865, i, ii; 1865–'6, i, ii; 1866–'7, i–iii; 1867, i–iii; 1868–'9, i–iii; 1869–'70, i–iii; 1870–'71, i–iii; 1871, i, ii; 1872, i–iii; 1873, i–iii; 1874, i–iii; 1875, i–iii; and special session, Adelaide, folio (53 vols.). Statistical Sketch of South Australia, by Josiah Boothby, London, 1876, 8vo.

From the Norwegian Government, Christiania: Norges Officielle Statistik, 13 volumes and 43 parts, Christiania, 1870–1876. Forklaringer til K. Norges Statsregnskab, 1875, Christiania, 1876, 4to.

From the second geological survey of Pennsylvania: Reports 1875–1878 (20 volumes).

From the Universities of Würzburg, Marburg, Berlin, Louvain, Bonn, Halle, Göttingen, Jena, Erlangen, Leipzig, Zurich, Greifswald, Heidelberg, Dorpat, and Freiburg: Inaugural dissertations for 1877.

From Dr. A. Ernst, Caracas: Statistical documents, 24 volumes, Caracas, 1875–1877, 4to.

From the Library of Parliament, Ottawa, Ontario: 18 volumes government documents.

From the State Library of Ohio: 14 volumes State documents.

An addition of special interest will be found in the palæontological library of the late Prof. F. B. Meek, whose death at the Institution, after many years' sojourn within its walls, was recorded in the report for 1877 (p. 10). Mr. Meek died without any known heirs, and his books being appraised in due legal manner, the Institution purchased them. This was the more desirable as, in regard to many of the works there was some uncertainty whether they had been presented to Professor Meek in his individual capacity or as the officer in charge of the palæontological department of the Institution. This question is, of course, now settled. The books of this library (especially the volumes enriched by copious manuscript notes and interpolations) have been repeatedly consulted by palæontologists and conchologists.

NATIONAL MUSEUM.

The relations existing between the Smithsonian Institution and the National Museum have been so frequently referred to by my predecessor that it is only necessary to mention briefly that the Museum constitutes no organic part of the Institution, and that, whenever Congress so directs, it may be transferred to any designated supervision without affecting the general plans and operations connected with the "increase and diffusion of knowledge among men." For the most part, the articles consist of the collections made by the United States surveying and exploring expeditions, and the expense of their care is entirely covered by government appropriations, which have been sufficient to meet the actual cost of maintenance and a restricted supervision, although with a larger fund the Museum could be placed on a more satisfactory basis, and one much more serviceable to science.

Attention has been called, in several previous reports of my lamented predecessor, to the importance of suitable provision for the accommodation of the vast amount of material now stored in the Armory building and in the basement of the Smithsonian edifice, and thus withdrawn from public examination. This surplus consists of the following essential elements:

First, the collections made by the United States exploring expeditions.

Second, the contributions sent by private individuals who reside in every section of the country.

Third, the exhibits of the Smithsonian Institution, the Indian Bureau, and the United States Fish Commission, at the Centennial.

Fourth, the donations to the United States by domestic and foreign visitors and commissions on that occasion.

The number of private contributions to the National Museum continues to increase in value and magnitude year by year, and embraces specimens of mineralogy and geology, objects of American antiquity, and other desirable articles. The government surveys, too, of Messrs. Hayden, Wheeler, and Powell have furnished a very large number of specimens of great value as illustrating the reports published by these parties. It is, however, under the two last-mentioned heads (the Centennial exhibits and donations) that by far the greater amount of this unexhibited material is comprised.

By means of an appropriation by Congress, as fully set forth in the Reports for 1875 (pages 8 and 46) and for 1876 (pages 8–11, 42, and 75–77), the Smithsonian Institution was enabled to exhibit a very full collection illustrating the animal and mineral resources of the United States; the Fish Commission to present every variety of boat, net, hook and line, harpoon, and other fishing implements, as well as models and illustrations of all the fishes useful for food or other purposes; the Indian Bureau to show a valuable representative ethnological series of ancient implements, of dressed figures, and of objects illustrating the life and customs of the North American aborigines.

At the close of the Exhibition, the foreign commissioners, induced by a desire to do honor to the United States, presented, with scarcely an exception, the whole of their exhibits (corresponding with those made by the Smithsonian Institution) to the United States Government, embracing the contents of many thousands of square feet in the different Centennial buildings. Of forty-one foreign commissions, thirty-four gave to the United States either the whole of their displays or a full series, probably representing 75 per cent. of all such matter as was shown under the patronage of the respective governments.

Many private exhibitors from abroad made similar contributions, some of these valued singly at over $20,000 each. A large proportion, too, of the more desirable exhibits by State commissions, as also of home exhibitors, was added to the mass, and nearly two months were spent at the close of the Exhibition in simply removing these articles to the government building and there packing them for transportation to Washington, a large force being required for the purpose.

The collection sent from Washington to Philadelphia filled twenty freight cars, and the donations received at the Centennial required forty more for their transportation, the entire amount to be brought to Washington making sixty car-loads, a quantity far beyond the storage capacity of the basement of the Smithsonian building.

In anticipation of these donations, Congress had previously authorized the transfer to the Smithsonian Institution, for the purpose of storage, of the Armory building, on the square between Sixth and Seventh streets, and made an appropriation to fit it up for the reception of the collections. To this building a portion of these collections was transferred, where they now fill four floors, of about 5,000 square feet each, from top to bottom, the remainder being stored in the basement of the Smithsonian Institution. At present, with the articles received from other sources, it is estimated that the quantity of objects not exhibited represents nearly five times the bulk of those at present displayed in the Smithsonian building.

It is to be understood, too, that these objects are not simply specimens of natural history, possessing an abstract interest to the student, but represent the application of natural objects to the industries, and as such are of great importance. In what is now a fairly complete series of economical minerals, such as ores, combustibles, building stones, clays, earths, &c., from all parts of the world, with their incidentals of reduction and application, and specimens of similar objects of art and industry derived from them, we have a collection of very great industrial importance, for it furnishes to the American manufacturer and designer information of the utmost value. The illustrations of means and appliances for the pursuit, capture, and application of food-fishes, from all parts of the world, are also of exceeding value, while the articles of Indian manufacture from Alaska, Washington Territory, and the Prybilov Islands are of the utmost interest.

Several donations from foreign countries are of considerable magnitude and importance; the first being from the King of Siam as a present to the United States Government; the second the display of the manners and customs of the Chinese made by the Chinese Commissioner; the third an exhibition of the industries illustrating the manners and customs of the Japanese, presented by the Japanese Government. The intrinsic value of all these objects presented to the United States is very great, having probably cost their respective contributors, either governments or individuals, not far from three-quarters of a million to a million of dollars.

The necessity, therefore, of some adequate means of displaying this rich collection, now withdrawn from the inspection of the public, has weighed very heavily upon the officers of the Smithsonian Institution, and several efforts have been made to secure an appropriation from Congress for the erection of a fire-proof building sufficient to contain it, but of the most inexpensive form of construction compatible with protection against fire, and allowing the greatest convenience of display. A plan was prepared on the basis of suggestions from General Meigs, and approved by the Committees on Public Buildings and Grounds of both the Senate and House. The Senate, at the second session of the Forty-fourth Congress, passed a bill appropriating $250,000 for the erection of a building of the kind, without a dissenting vote. This also passed the House; but obtained only a majority vote, under circumstances requiring a two-thirds vote.

A bill making an appropriation for the erection of such an edifice was again introduced into Congress at the current session, which it is hoped will be more successful. Owing to the particular form of construction of the proposed building, it can be completed in probably not more than a year, and the collections removed into it.

It is now proposed to place this building in the southeastern corner of the reservation of 52 acres, situated between Seventh and Twelfth streets and North and South B. It will be so situated as not to obstruct the view of the Smithsonian from the Capitol or from any other important point. As originally contemplated, the building was to occupy the space between the present Smithsonian edifice and Twelfth street; but it was finally concluded that if placed there it would obstruct the view of the Agricultural building, and the change of location was accordingly determined upon.

Attention was called by the report for 1877 (page 36), to the continued increase of the number and variety of the collections received during the year, the exceptional year of the Centennial being the only one that furnished a larger quantity of material. The returns for 1878 have again been much larger than usual, exceeding considerably those of the previous year. The total number of donors was 635 for the year, to 335 in 1877, of which 180 were contributors to the collections of the United States Fish Commission at Gloucester. The number of donations was 455, to 489 in 1877; and of separate packages 1,197, to 815 in 1877. A large part of the increase is due to the extensive contributions made to the United States Fish Commission by the fishermen and merchants of Gloucester, Mass., in which city the Commission has had a station for the prosecution of researches and the propagation of food-fishes during the last half of the year. The hearty appreciation, by all classes of the community, of the operations of the Commission, caused those fishermen residing at the port to save many articles brought up on the trawls from the deep water, and to bring them to the office of the Commission at Gloucester. The result is to be seen in several hundred donations, some of them embracing specimens of very great interest, and adding largely to our knowledge of the distribution of animal life in the waters off the coast of New England. As the result of these contributions, together with the gatherings of the Fish Commission itself, many species of fishes and of marine invertebrates have been added to the fauna of the country, several of them being entirely new; others were previously found only in the deep waters off the European coast or in those of Spitzbergen and Greenland.

Reference is, of course, quite impossible to even a small percentage of those collections added to the National Museum during the year covered by the present report, and they will be found under the names of the donors, alphabetically arranged, in the appendix. Even this, however, fails to give a complete idea of the magditude of the additions, as a collection embracing from five to twenty or more boxes may be included in a single line of the record. The books of the Institution, in which all these articles are entered systematically, give a more detailed statement; and the fact that a portion of these has required 9,973 entries, will furnish some idea of the aggregate.

Among the more important general collections received are those made by the United States Fish Commission at Gloucester, as already referred to, embracing a complete and exhaustive series of the marine animals of the ocean between the New England coast and that of Nova Scotia, Newfoundland, and the outer Banks, including the Georges, the Grand Banks, Flemish Cap, Le Have, Bank Quero, &c. This material embraces a great many duplicate specimens, which will, in time, be distributed to the educational and scientific establishments of the United States.

Next to this in importance and magnitude are two collections from the far North, one from E. W. Nelson, Signal Office observer at St. Michaels, in Alaska, consisting very largely of ethnological articles and birds; the other made by Mr. L. Kumlien, while a member of the Howgate expedition to Arctic America, this embracing much the same class of objects as those sent by Mr. Nelson.

The collection of birds and ethnological articles, gathered by Mr. Ober in the islands of the West Indies, to which further reference will be made, has also been of great moment. Mr. J. Zeledon, formerly an assistant in the Institution, and for many years resident in Costa Rica, visited Washington in the spring of 1878, bringing a very large collection of birds, mammals, &c., of his country.

Large collections have also been received from Lieut. George M. Wheeler, the proceeds of the expeditions of 1877 and of earlier years, transmitted by him in accordance with the law of Congress requiring their deposit in the National Museum.

In another part of the report will be given a more detailed account of some of the explorations to which reference has been made.

Following the plan of previous reports, we shall now proceed to indicate, briefly, the character of the more important additions to the Museum in systematic sequence with some reference to the result in increasing our knowledge of particular regions.

Anthropology.—Beginning with anthropology as the most interesting and important of such additions, I may refer again to the collections made by Mr. Nelson at Saint Michaels. These are very exhaustive and complete, and taken in connection with those sent by Mr. Lucien M. Turner from the same region supply a very full illustration of manners and customs of the Indian and Esquimaux races found in northwestern America. A special feature of Mr. Nelson's collection, like that of Mr. Turner, is the immense variety of carvings in bone and wood, representing various animal forms either in contour or in simple lines; the latter calling to mind the engraving upon bone, especially of antlers of reindeer found in the caverns of France and Germany, and throw much light upon the region and character of these remains. Many models of boats, traps for securing animals, fishing apparatus, articles of clothing, and many other objects constitute the mass of the great collection sent by Mr. Nelson.

Not at all inferior in interest, and only less in extent, are the collections of Mr. Kumlien made by him during several months' residence at Cumberland Gulf, in Arctic America, and on the opposite coast of Greenland. They include great numbers of ancient stone implements found in the Esquimaux graves, and supply a previous deficiency in the collections of the National Museum. There are also many articles of dress and adornment, implements of war, and the chase, &c. In the last year's collections of both Mr. Nelson and Mr. Kumlien are many stone implements, objects of horn, bone, or wood, illustrating in a very high degree the functions and applications of certain articles of stone familiar to the American archæologist, the uses of which were previously conjectural. These embrace scrapers, knives, planes, gouges, drills, and many other articles.

During the past year the attention of the Institution has been called especially to the subject of the soap-stone quarries, where the aborigines obtained their material for soap-stone bowls, dishes, &c., constituting so common a feature in American archæology, but the source of which has been heretofore but little noticed. Of these quite a number were met with during the year, and an examination more or less extensive has been made of each under the auspices of the Smithsonian Institution.

During the spring of 1875, some specimens of steatite were received from the quarry of John B. Wiggin, in Chula, Amelia County, Virginia. Among these were fragments of rude vessels, which, from their number and unfinished condition, were regarded as indicating that the place in question was once an aboriginal mine. Mr. Wiggin was requested to carefully save and forward all specimens of the kind which he might discover; and the receipt from him during the centennial year of an additional collection proved beyond doubt the correctness of the conjecture.

Inasmuch as, at the time, no quarry of this kind had been discovered,* and as, moreover, aboriginal methods of mining and working pot-stone were entirely unknown, it was thought advisable to have a careful exploration of the place undertaken, which was intrusted to Mr. F. H. Cushing, who visited the locality in June last, causing excavations of sufficient extent to be made to reveal a large portion of the rock-surface worked by the Indians. Again, in August and September, furnished with suitable instruments, and a complete photographic outfit, he continued these investigations, and, with the sanction and kindly aid of Mr. Wiggin, was enabled to greatly extend the diggings, thus making his examination very thorough and sufficient.

The surface indications of aboriginal quarrying were found to be shallow circular depressions, from ten to seventy feet in diameter. Mr. Cushing began operations by causing a space of earth, 60 feet in length by 40 in width at the base, to be cleared away from the center of the largest of these depressions. Everywhere over the rock-surface, thus exposed he found grooves and hollows made by the Indians in taking out sugar-loaf shaped masses of the rock; and throughout the soil removed he found numerous fragments of these masses mostly hollowed as the beginning of pots, together with equally numerous rude quartz-picks, some broken axes and mauls, and a few hammers of soapstone, which had been used in quarrying and working the material.

From the base of the triangular excavation a cutting was made, about 17 feet in width by nearly 40 in length. This was extended to the left 18 feet, to remove the earth from around a large out-cropping bowlder, from the base of which it was found that the Indians had cut the rock away piece by piece, until only a slender stem remained as its support. Another extension, nearly 40 feet to the right and 30 feet wide, laid bare one side and the center of a second quarry almost as much worked as the first. From this last a ditch 3 feet wide was carried forward more than 80 feet, all along the course of which were found Indian cuttings wherever the rock-surface was exposed. Thus the area worked over by the aborigines in one direction was shown to be not less than 180 feet. How far to either side of this their work extended can only be conjectured. The number and extent of those depressions not excavated, however, seemed to indicate that less than one-third of the Indian work was exposed by the diggings just described. Mr. Cushing not only procured from the earth removed, a collection of several hundred specimens, but also made and brought away photographic views and accurate plaster models of portions of his diggings.

Attention being drawn to these explorations while in progress by notices in some of the Washington newspapers, Mr. Elmer R. Reynolds, of the city, brought to notice some similar specimens of vessels which he had found within the District, on Soapstone Run, a branch of Rock Creek,

* Intelligence had been received of some surface workings in Chester County, Pennsylvania; so slight, however, that they could hardly be regarded as quarryings.

which were recognized at once as indications of another quarry, and Mr. Cushing was directed to make a thorough examination of it. Here, as in Virginia, depressions along the hill-side in which the quarry occurred showed that the Indians had worked the underlying ledge, although excavations subsequently made revealed the fact that they had depended mainly upon surface material for their supply. Large numbers of unfinished vessels, quartz-picks, hammer-stones, &c., were here found.

Another quarry has been repored by its proprietor, Mr. M. E. Holmes, as occurring on the right bank of the Potomac above Little Falls. This, though rich in ancient remains, has not yet been thoroughly examined by the Institution.

Mr. J. D. McGuire, of Ellicott City, Maryland, called our attention to still another quarry, not unlike the one on Rock Creek, and remarkable for the fine specimens of Indian work that it furnished. Through the hospitality and kind assistance of this gentleman, Mr. Cushing was enabled during the month of December to make a personal examination of the plàce, and secure for the museum nearly two hundred superior specimens.

It may be well to add that since the discovery of the Virginia quarry, public attention having been drawn to this kind of research by widely circulated newspaper notices, similar sources of aboriginal supply have been discovered in Rhode Island, Massachusetts, Connecticut, Pennsylvania, Tennessee, Georgia, Alabama, and Wyoming, from several of which the Institution has already received specimens.

An aboriginal quarry, recently discovered near Providence, R. I., on the farm of Mr. Angell, was visited by myself in July, accompanied by Professor Jenks, through whose assistance I was enabled to obtain specimens of the unfinished pots and of the mining apparatus.

Reference has already been made to the plans of an extensive work on the American Stone Age, to be prepared under the direction of the Institution, to serve as a manual for this department of archæology. The publication of the circular referred to as among the publications of the Institution for 1878 has been of great benefit in bringing in both large and small collections, as will be seen by reference to the list of donations. Every part of the country is represented in these returns, which are so many indeed as to render it somewhat invidious to select any for special notice. Justice, however, to the contributors, makes it proper that I should mention a few of these in greater detail.

The first collection to be noted is that presented by Mr. A. B. Crittenden, of Middletown, Conn., a large and extensive one, made during several years of effort. This is particularly rich in the shell heap or Kjökenmoedding deposits, from Cape Cod, showing a variety and complexity not previously exhibited.

To one correspondent, Mr. J. E. Gere, of Riceville, Wisconsin, of the Institution, is indebted for an important increase of its collection of ancient copper implements. Mr. Gere, during a visit to the Institution, three years ago, had his attention called to the paucity of such objects in the National Museum, and offered his assistance in obtaining and forwarding such specimens. As the result of his promise, the Institution has received from him during the year a large number of these articles, greatly adding to the variety of the series. Masses of native copper, plowed up by Mr. Gere on his own farm, were sent to illustrate the source of the material of these implements, and to show that it does not necessarily follow that it must have been obtained in barter or otherwise from the copper mines of the Lake Superior region.

From Mr. William Brady, of Minong, in the Lake Superior region, was received a barrel of hammers, used by the ancient miners in that vicinity, enabling us to make a very interesting comparison between these and corresponding instruments used by the Indians in working the soapstone quarries already referred to.

The collections received from Dr. Frank L. James, of Arkansas, are of great beauty and variety, as also those from Professor Randle, of Kentucky.

The result of long-continued examinations of shell mounds in Florida by Mr. Henry J. Biddle, of Philadelphia, is also of very great value.

Dr. Benjamin H. Brodnax, of Louisville, in continuation of previous sendings, has contributed articles of special interest; and the collections made in Lancaster County, Pennsylvania, by Dr. T. H. Bean and Mr. Galbraith, have also added greatly to the specimens from that State.

Among the more important collections received from regions outside of the United States is a number of implements, vases, &c., from Peru, presented by Mr. W. W. Evans, who has been for many years a correspondent of the Institution, and a contributor to the National Museum.

The archæology of Japan is represented by collections received from Professor Morse, consisting of shell-heap pickings and mound diggings on the Japanese coast. The fragments of pottery in this collection are rude and unfinished, scarcely more advanced than those found in the ancient graves and mounds of North America. They are supposed to have been the production of the Ainos of the early days, who are believed to have occupied, at one time, the entire country.

An interesting contribution to European anthropology was made by Professor Kollmann, who presented a series of crania of the earlier, although scarcely prehistoric, inhabitants of Germany.

Mammals.—While many single specimens or small collections of mammals have been received from various parts of the country, those received from Lieut. George M. Wheeler, of the Engineer Bureau, representing quite a variety of species, collected by Mr. Henshaw and other collaborators of the survey, deserve special mention.

A series of the seals of Arctic America, both of skins and skeletons, brought back by Mr. Kumlien, supplies a very important gap in the collections of the National Museum, exhibiting the variations of condition in several species, from the fœtal to the adult state, of both sexes, with corresponding skeletons of all these gradations.

The collection brought by Mr. Zeledon includes nearly all the known mammals of Costa Rica, from the largest to the smallest, and in most admirable condition of preservation, well fitted to mount for exhibition in the National Museum.

The Zoological Society of Philadelphia has presented a specimen, in the flesh, of the *Aodad* (*Ovis Tragelaphus*), which died in the menagerie of that establishment.

From the Public Library and Museum at Calcutta, in India, under the direction of Mr. Murray, was received quite a number of specimens of Indian mammals, including skins of the smaller kinds, and a considerable number of stuffed heads of tigers and other felidæ, as well as several crania of much value.

Birds.—The collections of birds received during the year have also been extensive and important, as shown by the number of specimens entered in the record book. Principally noteworthy is the donation by Mr. George B. Sennett, of Erie, Pa., of a series of the collections made by him during the preceding year in the vicinity of Brownsville, Tex. This embraces several species new to the Museum. In view of their admirable preparation, it is proposed to mount the greater part of them for permanent exhibition in the Museum.

From Dr. James C. Merrill, U. S. Army, stationed at Brownsville, Texas, was also received a very acceptable collection of skins and eggs of birds, from that region.

The collections of Mr. Nelson in Alaska and of Mr. Kumlien in Arctic America, already referred to, embrace many species of much interest, although none actually new to the Museum.

The more important addition made to the collection has been a series of oceanic birds, found off the coast of the United States. Mr. Raymond L. Newcomb having been sent out by the Smithsonian Institution on board the schooner Marion, Captain Collins in command, for the purpose of ascertaining what were the birds occurring on the fishing-banks, in such numbers as to be serviceable in furnishing bait for the capture of codfish, he brought back a large and well-prepared collection, embracing some quite rare species, although none previously unrepresented. Some of the plumages were new, and it became possible, from the collections and his notes, to interpret the meaning of various appellations employed by the fishermen.

For the assistance rendered to Mr. Newcomb, as well as in furnishing information to the Fish Commission, Captain Collins and his crew deserve special mention.

Of extra-limital collections, those made by Mr. Fred. A. Ober in the West Indies, referred to in another part of this report, are of particular value and importance. As the result of these the National Museum is now in possession of by far the most complete series extant of birds of the West Indies, showing better than any found elsewhere the geographical distribution peculiar to each island, and the precise distribution of those common to two or more islands.

To this end especially have contributed the labors of Dr. Henry Bryant, in the Bahamas, and of Mr. William T. March, in Jamaica; of Dr. John Gundlach, Mr. Charles Wright, and N. H. Bishop, in Cuba; of Mr. Alfred Newton, in Santa Cruz; of Mr. George Latimer, and Mr. Thomas Swift, in St. Thomas and Porto Rico; of Dr. Bryant, in Porto Rico, and of Mr. Galody, in Antigua.

Not only were many species previously described contained in Mr. Ober's collection, but he furnished types of nearly twenty new species.

A series of memoirs, by Mr. George N. Lawrence, published in the "Proceedings of the National Museum," includes lists of the collections and embraces descriptions of the new species.

From foreign regions an interesting collection, for the most part of water-birds, was sent from the Bosphorus by the Robert College of Constantinople, and one from the coast of Syria by Mr. William T. Van Dyck.

Reptiles.—Reference has been made in previous reports to a very extensive collection of casts of American fishes which were prepared originally for exhibition at the Centennial, and continued since then by the addition of new species, coming to the Institution in proper condition for reproduction.

It was determined to include the North American reptiles in the series of life reproductions of such objects as are not easily exhibited as stuffed specimens. In order, therefore, to secure living objects from all parts of the country, a circular was distributed, inviting contributions of serpents, frogs, lizards, and salamanders, in all their variety; and, as in previous appeals from the Institution for assistance, the response was generous and extensive. A large number of specimens, both of rare and common species, was received, and kept the entire force of Smithsonian artists occupied during the year.

Resulting therefrom, the National Museum now has an extremely interesting and attractive collection of these animals in their natural attitudes, either as plaster or papier maché models, and very carefully colored from sketches made while the animals were alive. In some cases it was found possible to make the casts from the living specimens, and in several different attitudes, from the same individual. As heretofore, the casting and molding have been under the direction of Mr. Joseph Palmer, assisted by Mr. A. J. Forney and Mr. William Palmer. The coloring of the reptiles has been performed by Mr. A. Z. Shindler; that of the fishes by Mr. J. H. Richard.

Besides the living reptiles referred to, quite a variety of species has been obtained from other sources, among others from Mr. Ober in his West Indian explorations. Dr. Ruth, U. S. N., the surgeon of the steamer Enterprise, in which Captain Selfridge made his exploration of the Amazon in 1848, also furnished a valuable collection from that river. From Dr. Hering was also received a collection of the species of Surinam.

Fishes.—As might naturally be expected, from the close connection of the operations of the United States Fish Commission with those of the Smithsonian Institution, the additions in this department have been especially noteworthy, and include not only various specimens of important scientific interest, but also many illustrating and attesting the propriety of national aid in the multiplication of useful food-fishes.

It is considered especially desirable to bring together in Washington a complete representation of the food-fishes of the United States, both inland and marine; and also such kinds from other countries as tend to illustrate the American species, or as may suggest future action in the way of their introduction and acclimation in the New World.

The series of species of the salmon family, contributed by Mr. Livingston Stone from the salmon-hatching establishment on the McCloud River, in the Upper Sacramento Valley; and those furnished by Mr. Charles G. Atkins, from his works in Bucksport and Grand Lake Stream in Maine, have constituted the most important additions of fresh-water species; while the special labors of the United States Fish Commission at Gloucester, Massachusetts, aided by the fishermen of that place, have brought to light nearly 20 forms of deep-sea fishes, previously unknown.

Next to the collections from the station of the United States Fish Commission at Gloucester, the most important additions to the marine fishes have been received from Mr. Vinal N. Edwards, for a long time an employé of the Commission, and stationed at Wood's Holl, whose vigilant attention to the subject brought to light a number of additional species; so that now the Wood's Holl record embraces nearly 140 different kinds.

From Mr. Silas Stearns, of Pensacola, while connected with the Pensacola Ice Company; from Mr. James C. Leslie, of Charleston; from Mr. Samuel Powel, of Newport; from Dr. Porter, U. S. A., and Mr. Moore, of the Tortugas, have come many additions to our knowledge of the distribution of species, through their contributions to the National Museum.

The Museum is also indebted in a very marked degree, as for many years past, to the services of Mr. E. G. Blackford, the well-known fish dealer of Fulton Market, New York, for the transmission of many valuable specimens. By an arrangement with the wholesale dealers and the fishermen, this gentleman is always notified of the appearance in the market of specimens that are believed to have an interest, either from their novelty or any other cause, and, in the exercise of an excellent judgment, whatever is thought will be valued in Washington is promptly transmitted to the National Museum. To no other single person is the Institution indebted for so many favors in this direction as to Mr. Blackford.

From the museum of the Wesleyan University, at Middletown, have been received a considerable number of fishes, collected in the Bermudas by Mr. G. Brown Goode; from Professor Felipe Poey also a number of

Cuban fishes, which have an especial value, as being types of his proposed memoir on the subject, which, should it appear on the scale contemplated, will be the most extensive work ever published on the fishes of any country.

From the west coast of the United States the most important additions have been of the fishes of Alaska, sent by Mr. E. W. Nelson, from Saint Michaels, and those of Puget Sound, by Mr. James G. Swan.

In the collection of fishes gathered in Cumberland Gulf by Mr. L. Kumlien, while connected with the Howgate Expedition, were several of kinds new to the fauna of northeastern North America, and others of great value as illustrating the species obtained by the United States Fish Commission at Gloucester, either by its own efforts or by the aid of the fleet of fishermen belonging to that port.

The Natural History Museum of Paris has contributed a series of the fishes of France and the Mediterranean. A series of the fresh-water fishes of Northern Siberia has been furnished by Dr. Otto Finsch as the result of his recent well-known explorations.

Among the more noticeable results of recent efforts to extend and increase the useful food-fishes of the United States, that have come to hand, are specimens of full-grown shad from the Sacramento River, contributed by Mr. Thomas Bassett; a pair of shad from the Ohio, by Mr. William Griffith, of Kentucky; a mature salmon from the Connecticut River, obtained through Mr. E. G. Blackford; one from the Delaware, weighing 23 pounds, presented by Mr. E. J. Anderson, Fish Commissioner of New Jersey; and one of 19 pounds, taken in the Susquehanna, by Mr. Frank Farr near the shad-hatching station of the United States Fish Commission, five miles below the railroad bridge at Havre de Grace. In addition to these, many specimens of young California salmon and of landlocked salmon have also come to hand.

Invertebrates.—In the department of invertebrates the collections have been largely confined to the marine species, especially as no particular effort is now made to gather the insects which form the great body of terrestrial forms. By an arrangement between the Smithsonian Institution and the Department of Agriculture, all the collections in the line of insects and terrestrial articulates generally are transferred to the care of that department, where, under the supervision of its entomologist, they are likely to render excellent service.

Of land and fresh-water mollusca quite a number of specimens have been received and properly cared for. Of marine invertebrata most gatherings have been secured, especially through the efforts of the United States Fish Commission, at Gloucester, the labor being performed under the special direction of Prof. A. E. Verrill, of Yale College, assisted by Messrs. Richard Rathbun and Warren J. Upham. In this service, however, the work connected with the collection and arrangement of the marine mollusca was under the direction of Mr. Sanderson Smith, of New York, a competent conchologist, the value of whose gratuitous services to the Fish Commission and to the Smithsonian Institution is not easily to be overestimated.

With the assistance of the extensive and powerful apparatus on board the Speedwell vast numbers of specimens of all kinds were secured, appropriately assorted, and packed by the gentlemen referred to, and are now in charge of Professor Verrill at New Haven undergoing the necessary examination for their arrangement and identification. A great number of duplicates was obtained for the purpose of supplying sets to educational and scientific institutions throughout the country.

A collection of fossiliferous rocks, brought up from time to time by the trawls from the various banks of the New England coast, and found in the possession of various citizens of Gloucester, by Mr. Warren J. Upham, while connected with the Commission, revealed, under the critical labors of Professor Verrill, Mr. Smith, and himself, the existence of a submarine formation quite different from any now known on the land, and embracing a number of new species, and others in peculiar combinations. The idea has been suggested by Professor Verrill that at some earlier day the whole or the greater part of the interval between North America and Europe, extending possibly as far north as Iceland, was occupied by a continent, which, after a certain amount of erosion and excavation, was submerged, the plateaus or highest remaining portions constituting a portion of the banks, which furnish such rich harvests. The indications of this deposit are believed to be found at Gay Head on Martha's Vineyard, and possibly at Siasconset in Nantucket, in the Georges, at Le Have and Quero Banks, the Grand Banks, Flemish Cap, &c. Of course so important a generalization will require further determinations, and it is hoped that the labors of the Fish Commission during the coming year may tend to solve the problem.

In the collections made by the several methods, and from the several sources referred to, are to be found all the orders and classes of marine invertebrata, such as radiates, mollusks, worms, crustacea, &c.

Apart from the collections of shells and of invertebrates referred to, we may mention a valuable collection of shells of Florida, presented by the Chicago Academy of Sciences, and of those of the German seas, by Professor Möbius.

Of terrestrial fossil remains from the land no important additions have been made. Among those received, however, there is an interesting and valuable collection of species from California, presented by Hon. A. A. Sargent, United States Senator from that State, and a Regent of the Smithsonian Institution.

Reference has been made to the arrangement with the Department of Agriculture, by which that establishment receives all the collections of land articulates; and a similar arrangement has been made in regard to the plants, special efforts in regard to that branch of natural history being left to the department. All the specimens offered spontaneously or collected by government expeditions have been turned over to the department as soon as received. The most important of these consist of a series of species from Japan and Asia, presented by the Botanic Garden of St. Petersburg. Professor Sargent, of the Botanic Garden at Cambridge, has contributed quite a number of valuable living aquatic plants for the purpose of embellishing the United States carp-ponds on the Monument lot in this city, and of furnishing desirable food for the herbivorous fish.

Dr. William G. Farlow, of Cambridge, while associated with the Fish Commission at Gloucester, made a large collection of marine algæ, of which, as heretofore, a part will be presented to the National Museum.

A circular issued by the Institution some years ago, relative to the habits, &c., of the grasshopper and other insects, elicited many responses, which were referred to Prof. S. H. Scudder. The material, however, was never fully worked up, and it has been transferred, with the consent of the Institution, by Professor Scudder, to the United States Entomological Commission lately organized by Congress.

I have thus furnished as briefly as possible a review of some of the more important contributions to the National Museum, but as the limit of space has prevented my going into much detail, I have been obliged to make selections from large numbers of contributions of value fully equal to those specially noted. All these, as stated, will be found in the list of donations entered in the record-books of the Institution. Every specimen received has, as far as possible, been recorded in its proper register, with a number affixed in some irremovable form; and whenever the size of the specimen would admit, with the name of the locality and of the donor attached. Of these entries no less than 9,973 have been made during the year, as shown by the table at the end of this Report. As heretofore explained, however, one entry may embrace a large number of specimens, especially of the same general character, without any special individuality, gathered at the same date, in the same locality, and received from the same person. It may fairly be assumed that the total number of pieces actually recorded and provided with numbers amounts to 15,000.

Considered with reference to geographical distribution—illustrating the several faunas of the various quarters of the globe, as would naturally be expected, by far the greater portion of these accessions has been received from North America, the regions from which the most important materials have been derived being Alaska, furnished by Mr. Nelson, Arctic America, by Mr. Kumlien, and the eastern coast of New England by the Fish Commission itself and its friends at Gloucester; of fishes and invertebrates from Puget Sound by Mr. Swan, fishes of the Upper Sacramento by Mr. Stone, fishes of Florida by Mr. Stearns, Dr. Porter, and Mr. Moore; and general collections by Mr. Ridgway, are among the most noteworthy.

From South America were received ethnological specimens from Peru, by Mr. W. W. Evans; fishes and reptiles from the Amazon, by Dr. Ruth, U. S. N., of the United States steamer Enterprise.

From Mexico valuable specimens have been received from Professor Dugés, consisting especially of mammals, birds, reptiles, and fishes; illustrations of the ethnology and zoology of Guatemala have been furnished by Dr. Flint and United States Minister Williamson.

Of the animals of Surinam, collections were sent by Dr. Hering; of the vertebrata of Costa Rica, generally in a large variety, by Mr. J. Zeledon; of the fishes of Cuba, by Professor Poey; general collections from various islands of the West Indies, by Mr. Ober; fishes of Bermuda, by the Wesleyan University, of Middletown, collected by Mr. Goode; fishes and archæological remains from Japan, by Prof. E. S. Morse; the fishes of France and the Mediterranean, by the Museum of Natural History, Paris; of Northern Siberia, by Dr. Finsch, of Bremen; skins, skulls, and heads of the mammals of India, by the Public Library of Kurrachee.

Mineralogy.—In the department of mineralogy and geology, as usual, additions of many specimens, including several large collections, have been received, as it has now become quite a common thing for people all over the United States to send samples by mail or otherwise to the Institution for determination.

Many valuable additions have been made by the officers of the Land Department of the Interior, especially by Mr. John Wasson, surveyor-general of Arizona, and Mr. Hardenberg, the surveyor-general of California. By far the most noteworthy and important addition in this line, has been that of the greater part of the Swedish exhibit of iron, steel, and other metals, made at Philadelphia in 1876. The valuable iron and steel exhibit by the Swedish Commission at the Centennial Exposition had in part been promised to the American Institute of Mining Engineers, and at its solicitation any effort on the part of the Smithsonian Institution to secure the remainder for the government was waived in its behalf. It appears, however, that the necessary arrangements for their acquiring this collection were not completed, and during the year 1878, Dr. Joshua Lindahl, the representative of Sweden in connection with the Permanent Exhibition, offered the remainder of the collection as it stood, to the National Museum. This proposition was, of course, very gladly accepted, and the collection was duly transmitted under the direction of Mr. Thomas Donaldson, including the greater part of the display of the Iron and Steel Mining Company of Motala, and the iron and steel of Sandvik, a well-known and conspicuous Swedish establishment.

The institution received also, on special deposit, through the aid of Dr. Lindahl, the immense mass of native iron, weighing five tons, the smallest of three nuggets brought from the island of Disco by the Swedish Government, the one referred to having been presented to Professor Nordenskjöld, who had charge of the transfer, and by him sent for exhibition to Philadelphia. Opinions of experts are at present divided as to whether this is actually of meteoric origin, or a representative of almost the single instance of metallic iron in considerable masses, as a native metal. Whatever be the actual fact, it makes no difference in the interest of the specimen; and its acquisition, even for a short time, by the National Museum, is a subject of congratulation.

Scientific investigation of collections.—As in previous years the collections of the National Museum, in charge of the Smithsonian Institution, have been freely open to the examination of competent investigators. It is preferred, of course, that this work be prosecuted in Washington; but where it is impossible to do this there is no hesitation in sending articles or collections, under suitable conditions, to any part of the world.

Most of this work of investigation is done by the resident naturalists connected with the Smithsonian Institution, directly or indirectly—the mammals by Professor Gill and Dr. Coues; the birds by Mr. Robert Ridgway; the reptiles by Dr. H. C. Yarrow and Dr. Bean; the fishes by Professor Gill, Mr. Goode, and Dr. Bean; the mollusks and marine invertebrates by Mr. William H. Dall; the insects by Professor Riley; the fossils by Prof. Charles A. White; the minerals by Dr. F. M. Endlich; the plants by Dr. Geo. Vasey.

Outside of Washington the principal collaborators have been, for the mammals, Mr. E. D. Alston, London, and Mr. J. A. Allen, of the Museum of Comparative Zoology, Cambridge, Mass.; for the birds, Mr. George N. Lawrence, of New York, Dr. P. L. Sclater, of London, and Mr. Osbert Salvin, of Cambridge, England; for reptiles and vertebrate fossils, Prof. E. D. Cope, of Philadelphia. These gentlemen have all rendered more or less service in this connection by investigating the specimens, identifying those that were previously known, and describing the new species.

Distribution of collections.—The extent of the distribution of specimens during 1878 will be seen by reference to the table at the end of this report. It has been quite large, and has furnished much educational and scientific material. It is expected, however, that a very much larger amount will be supplied during the year 1879. There is a great number of duplicates of minerals, rocks, fossils, &c., which cannot be reached until the liberality of Congress shall appropriate the necessary means to erect the new building for the National Museum. Such building is required even for the unpacking of the specimens and the separation of the series to be reserved for permanent display. This will leave a large quantity of surplus material, of considerable variety, which will enable the Institution to supply to a good degree the wants and applications of many colleges, academies, and scientific societies throughout the country.

GALLERY OF ART.

The principle of co-operation and not of competition which has for so many years been the basis of action of the Smithsonian Institution, finds a portion of its expression in the arrangement with the Corcoran Art Gallery. Its pictures, statuary, and engravings have for the most part been removed to the Gallery, and the remainder is being prepared for the same destination. They are not presented to the Gallery, but simply deposited, and are subject to reclamation at any time.

For many years Professor Henry was one of the trustees of the Corcoran Gallery, and was thus able to look after the interest of the Institution in its collections. I have been honored by receiving a similar appointment at the hands of the board of trustees.

The propriety of the action of the Board of Regents in directing that a first-class portrait of Professor Henry be painted, the work being executed in April, 1877, by Mr. Le Clear, of New York, has been fully justified. His picture is now exhibited in the Regent's room in the Institution, after having been displayed for a time at the Corcoran Gallery. Several excellent crayon heads, of life size, of Professor Henry have been executed by Mr. Ulke and copies have been ordered for Princeton College and other institutions where Professor Henry's was an honored name.

UNITED STATES FISH COMMISSION.

Attention has been called in the reports of my lamented predecessor to the extent to which the time of the officers of the Smithsonian Institution has been occupied in the prosecution of labors undertaken by direction and in behalf of the general government; his own record of twenty-six years' service in connection with the Light-House Board, for a large portion of the time its chairman: his service on various special boards, such as those for the selection of building-stones for the Capitol, for the consideration of the question of ventilation of the Hall of the House of Representatives, &c., and in many other cases, furnishing ample illustration.

My own more immediate relations to the general government commenced in 1871, when Congress passed an act authorizing the appointment of a Commissioner of Fish and Fisheries, to investigate questions connected with the condition of the fisheries of the sea-coast and the lakes, and providing that the appointment should be by the President and confirmed by the Senate, and that his services should be rendered without compensation.

Having received the appointment from the President, I commenced the work by an investigation, of several months' duration, of the condition of the fisheries on the New England coast, especially as to the supposed conditions affecting their extent and development.

In 1872 the subject of the propagation of food-fishes in the waters of the United States was added by Congress to the other duties of the Commissioner, and since then his time has been largely occupied with the prosecution of researches into the American fisheries and in the propagation and distribution of various desirable species into every State in the Union. Previous reports will be found to contain general statements of what has been done each year; and I shall therefore give a brief account of what was done in 1878, premising that the appropriations, beginning with $5,000 in 1871, have increased with each year, until those for 1878 amounted to $78,200.

The work of the Fish Commissioner is now prosecuted under the two distinct heads of inquiry, and propagation, each with a corps of assistants, for the most part occupied in different regions of the country. The propagation department has special reference to the shad, the salmon of California, the salmon of Maine, the land-locked salmon, the white-fish, and the carp.

The invention of apparatus by Mr. T. B. Ferguson, one of the fish commissioners of Maryland, by which the hatching of shad could be prosecuted on a much larger scale than before, and under more convenient circumstances, marks a new era in the art of fish culture, experiments made by him in 1877 having been extensively prosecuted by the United States Fish Commission in 1878.

For the purpose in question four scows were fitted up in Baltimore, two with suitable machinery and apparatus, and two as quarters for the men. These were taken to Albemarle Sound and established at a point on the fishery of Dr. Capehart, of Avoca, by whom every assistance was rendered in the supply of ripe fish, from which 10,000,000 of young fish were hatched out and deposited in adjacent waters or transferred to distant points.

After the season for work in that vicinity had passed, the vessels were taken to Havre de Grace and anchored about five miles below the railroad bridge, in a sheltered cove. Here a much larger number of fish was hatched out, and the young were distributed by special messengers throughout the Union. The work of distribution of the young shad was under the special supervision of Mr. James W. Milner, first assistant of the commission; Mr. T. B. Ferguson, fish commissioner of Maryland, the inventor and constructor of the hatching apparatus, however, having charge of the propagation of the shad here, as also during the greater part of the sojourn at Avoca.

The result of the new experiment was perfectly satisfactory, and so far as relates to the shad in the future, there is no limit to the amount of work that can be done other than that of the number of ripe eggs procurable.

The labor of obtaining the eggs of the California salmon at the United States hatching-station on the McCloud River, in the Upper Sacramento Valley, was also carried on on a much larger scale than ever before, it being possible, as the direct result of the propagation in the earlier part of the operations of the commission, under the charge of Mr. Livingston Stone, to procure as many eggs as were called for; and no less than 15,000,000 eggs were obtained, and partly developed, and then distributed to various State commissioners and other parties, by whom they were hatched out and planted in the waters. A large number was hatched on account of the United States Fish Commission by Mr. Frank N. Clark, of Northville, Mich., and by Mr. Ferguson, at Baltimore. These were distributed to such of the Southern and Western States as were without arrangements of their own for prosecuting the work.

Nothing was done with the eastern salmon; but the favorable results of the work initiated five or six years ago, in restoring this fish in large numbers to the Merrimack and the Connecticut, and in planting them in the Delaware and the Susquehanna, will probably induce the renewal of the station at Bucksport, Maine, during the coming year.

The operations connected with securing eggs of the land-locked salmon at Grand Lake Stream were entirely successful, although not so many were obtained as last year. These are now in process of incubation, and will shortly be distributed.

Congress appropriated a sum of money for the purpose of fitting up the two lakes in the vicinity of the Monument in the city of Washington for the culture of European carp, a considerable number of the best varieties having been obtained in 1877, and deposited with the kind permission of the Park Commissioners in the ponds of Druid Hill Park, in Baltimore. When the Monument lot ponds were in proper condition a portion of the fish were transferred from Baltimore to their new quarters, where it is hoped they will find a congenial home. A distribution of the young will probably be made in the course of 1879, enough, it is hoped, to meet a part, at least, of the demand which has already sprung up for supplying fish-ponds throughout the country.

The most important progress in practical fish culture has been made by the United States Fish Commission during the year, in the application of its methods to the production of the sea-fishes. Experiments were instituted at Gloucester, in Massachusetts, in reference to cod, the spawning season of which takes place in the winter. The establishment was properly fitted up and, after varying results, the proper method of developing them was ascertained. Many millions of the young fish were hatched out and deposited in the waters, and about 20,000 sent on to Washington for exhibition to members of Congress, and others interested in the experiment. Nothing has yet been done with mackerel, but it is believed that the arrangements prepared for the cod will be equally efficient for that fish, as also, probably, for the halibut, while many other species, such as the tautog, sea-bass, and scup, can be treated in the same way.

The importance of this new departure of the United States Fish Commission cannot be overestimated, as it gives us the means of improving, at small expense, the sea fisheries of our coast, and also furnishes the opportunity of establishing them at points where they do not at present exist. Thus, by carrying the young cod from Massachusetts and planting them on the coast of New Jersey or Maryland, of Virginia or North Carolina, there is every assurance that, in accordance with the universal rule, these fish, when ready to spawn, will return to their starting place and become the means of establishing profitable fisheries to the inhabitants of the region. It is well known that in the Southern States the fisheries, contrary to the fact in the Northern States, are of little moment in the winter season, the most prominent species coming up in the spring and returning as the waters become chilly. The establishment of cod fisheries, and possibly of those of halibut, as winter fisheries along the southern coast, will therefore be of great importance.

The second branch of the Fish Commission's work, namely, that of the investigation of the sea fisheries, was carried on at Gloucester for three months, with the co-operation as heretofore of the Secretary of the Navy in furnishing a suitable vessel, and the general work was done with more efficiency and completeness. The same vessel, the United States steamer Speedwell, used in 1877, was detailed by the Secretary for the service, and was in command of Capt. L. A. Beardslee, who had previously sustained similar relations to the Commission when in charge of the steamer Blue Light.

The longer period of service of the vessel and the more favorable station enabled the Commission to perform a very large amount of work, the results greatly exceeding those of any previous year. Important determinations were made of the character of the sea-bottom, of the temperature and chemical constituents of the sea-water at different depths, the currents, &c., while the exhaustive collections of marine animals and plants showed clearly the character of the food of the fishes, and at the same time furnished a vast amount of natural history material of the greatest scientific interest. As heretofore, special efforts were made to obtain a large number of duplicates, so that by their distribution in named sets the colleges and other educational establishments of the country might participate in the results of the labors of the Commission.

As heretofore, the labors of the Commission at Gloucester, connected with the invertebrate department, were in charge of Prof. A. E. Verrill, of Yale College, New Haven, assisted by Mr. Sanderson Smith in the department of the mollusca, and by Mr. Richard Rathbun and Mr. Warren J. Upham. The collections made, as in previous years, were placed in the hands of Professor Verrill, who is now engaged in their classification and arrangement in sets. Dr. William G. Farlow, of Cambridge, as usual, spent considerable time with the Commission, and devoted himself especially to the investigation of the marine algae.

The investigation into and classification of the various kinds of fish brought in were in charge of Mr. G. Brown Goode, a collaborator of the National Museum, assisted by Dr. T. H. Bean, of the same establishment, and by Mr. R. E. Earll.

Capt. H. C. Chester had general charge of the laboratory and the direction of the actual dredging and trawling on the steamer.

The special superintendence of the hatching of the codfish was conducted by Mr. J. W. Milner, with the assistance of Mr. R. E. Earll. The propagation department was in charge of Mr. Frank N. Clark, of Michigan. The machinery was superintended by Capt. H. C. Chester, and it is to his ingenuity that we owe the construction of the apparatus by which the actual work of hatching the codfish was rendered practicable. The difficulty of using the apparatus employed for hatching shad arose from the fact that while the eggs of the shad are heavier than the fresh water, those of the cod are lighter than the salt water, and new conditions had to be devised to keep the eggs down instead of lifting them up. This problem, as already stated, was satisfactorily solved, after many experiments, by Captain Chester, who is therefore entitled to much credit for the success of the work.

HALIFAX COMMISSION.

In 1871 a convention was held by the United States and Great Britain, at Washington, for the purpose of settling certain questions at issue between the two governments, notably that of the depredations upon American commerce by Confederate cruisers, fitted out or supplied in British ports; and also certain disputed points in reference to the fisheries of British North America.

The treaty agreed upon was not ratified by the several contracting parties, consisting of the United States and the five British maritime provinces, until 1873, when commissioners were duly appointed by the respective governments, Mr. Alexander T. Galt being named by Great Britain; Governor Clifford, of New Bedford, by the United States, and Mr. Maurice Delfosse, the Belgian minister to the United States, as the third. For various reasons, and partly owing to the death of Governor Clifford, no definite action was taken until 1876, when Mr. E. H. Kellogg, of Pittsfield, Mass., was appointed to succeed Governor Clifford; and the place of meeting was fixed at Halifax, Nova Scotia, on the 15th of June, 1877, and after receiving the British claim the commission adjourned until the 28th day of July, 1877, when it reassembled and continued in session until nearly the stipulated limit, in the month of November.

The United States commissioner was assisted by Mr. Richard Henry Dana and Mr. William H. Trescott. The British commissioner had, as his counsel, one distinguished gentleman from each province, namely, Mr. Joseph Doutre, for Canada; Mr. S. R. Thomson, for New Brunswick; Hon. W. V. Whiteway, for Newfoundland; Hon. Louis H. Davies, for Prince Edward Island; and Mr. R. L. Weatherbe, for Nova Scotia.

At the request of the Secretary of State, I attended the meeting at as early a date as my other duties would permit, arriving on the 17th of August, and remaining until the 21st of October.

The British commission had on its side the minister of marine, Mr. A. Smith, assisted by Mr. W. F. Whitcher, the commissioner of fisheries.

The deliberations of the court involved a careful consideration of all the facts and statistics of the two countries, and a vast amount of information relating to the subject was brought together in the form of testimony of witnesses and experts and by the presentation of tables, reports, and digests. The volumes of the reports of the proceedings of the commission constitute a rich field for the naturalist as well as the statistician.

Material service was rendered by the United States Fish Commission, in the collection of important statistics gathered expressly for the purpose, especially in the presentation of tables, showing the catch of fresh fish along the coast of the United States within the treaty limits. This work was more particularly under the charge of Mr. G. Brown Goode, who executed it to the entire satisfaction of the American counsel.

The occasion was made use of by me to collect information and to prepare a systematic account of what is known of the habits of the cod and mackerel, and the various methods of capturing them, the bait to be used, &c., which will form the subject of special reports hereafter.

The award of five and a half millions of dollars, as representing the value to Great Britain of the privileges conceded to the United States, has given very great dissatisfaction in this country, to the New England fishermen especially, who denounce it as unjust in the highest degree, and express the hope that at the earliest possible moment the treaty will be abandoned, even if the original condition of things be restored.

The very great lack of published information on the subject of the American fisheries, as compared with the extremely methodical and precise summaries of the Canadian authorities, has induced me to give especial attention to this subject for information in the future, and with the co-operation of the State Department, which has placed a small fund at my disposal for the purpose, I am engaged in collecting, collating, and digesting the facts and statistics in reference to the American fisheries, an information doubtless of much value on the occasion of another arbitration similar to that at Halifax. This work is more particularly in charge of Mr. Goode.

To ascertain the accuracy of the figures presented at the Halifax convention as to the catch by citizens of the United States of mackerel off the American and Canadian coast, I employed Mr. Alexander Starbuck, of Waltham, Mass., to make a new digest of the records, as shown by the State inspections of Maine, New Hampshire, and Massachusetts. His work has been completed and shows a material difference from the old figures, but without affecting the strength of the American case.

Statistics of sea fisheries.—Reference has already been made to the data relative to this subject at Halifax, and the intention on the part of the commission to secure reliable records of the catch, export, and consumption in the United States of the more important fish. For this purpose circulars were issued, requesting answers to certain questions relating to the habits, mode of capture, statistics, and disposition of the cod, the mackerel, the mullet, the alewife, and the smelt. Also another blank inviting information as to the extent of the fishery marine, the nature of the crews, the tonnage of the vessels, the apparatus used for capture, and other incidentals. For the purpose of collecting this information, Mr. Vinal Edwards, of Wood's Holl, an assistant of the commission, was detailed to visit the fishermen along Buzzard's Bay and Vineyard Sound and obtain the data which were needed for the various purposes referred to. This was found to supplement very satisfactorily the valuable body of statistics now being collected under the direction of the commissioners of inland fisheries of Massachusetts. These gentlemen have been authorized by the legislature to require a report of the statistics in regard to the character and catch of all the pounds, weirs, and gill-nets in the commonwealth.

The results of these several circulars will be published in full in future volumes of the report, and I take great pleasure in referring to the first of the series—namely, that upon menhaden, as prepared by Mr. Goode. This is a most exhaustive and complete history of the subject in all its relationships, scientific, biological, and economical. It occupies 520 pages, and is illustrated by 30 plates. It forms one of the same series with the exhaustive paper by Mr. Starbuck upon the whale fisheries, published in the fourth volume of the reports of the Commission.

It is also proposed to direct special attention to the history of the Southern mullet. This fish in many respects represents and may be said to replace in the South the mackerel in the North. It occurs in enormous numbers, indeed such as to permit its capture in even larger quantities than the mackerel, coming in shore to spawn in immense numbers in the autumn months. It is not at all improbable that a catch of half a million barrels could easily be made, and under circumstances involving very much less expense and exposure than would be needed for taking one-quarter that number of mackerel. It is caught abundantly all the way from North Carolina southward into the Gulf of Mexico, and is destined at no distant day to represent a very important element in the resources and business of the South. At present the methods of taking and curing the fish are very inferior to those practiced in regard to the mackerel, and the fish is consequently less esteemed; but it is not improbable that in time it will be found to occupy an almost equal rank as a food-fish, and a much more important one as an article of commerce.

Another subject to which the attention of the Commission is being directed is a similar inquiry in regard to the lake herring, the white-fish, and the salmon trout, all of them species captured and cured in great quantities, and dividing with the mackerel and the cod the demand of the market.

MISCELLANEOUS.

Mr. William H. Dall, for many years an associate of the Institution, in charge of its department of conchology and marine invertebrates generally, spent several months in 1878 in a visit to Europe, especially to the zoological museums and to the co-workers in his special department of research in Northern Europe. Acting as an accredited agent of the Smithsonian Institution, he was authorized to offer its services to specialists in prosecuting their researches, and to invite exchanges of books and specimens. Many valuable alliances have been formed in consequence of this visit, and the Institution has had already the pleasure of supplying considerable material in response to calls for the same.

Availing ourselves of a visit to France in 1878, by Mr. Thomas Donaldson, whose services to the Institution during the Centennial Exhibition had been of great value, that gentleman was requested to call on Mons. de la Batut, who had presented the Institution with relics of James Smithson, and procure from him all the information he could furnish relative to the founder of this Institution. Mr. de la Batut is the half-brother of the nephew of Smithson, to whom the latter bequeathed his property, and in case of whose death it was to be devoted to founding the Smithsonian Institution. Mr. Donaldson visited Mr. de la Batut, and gathered from him a few facts of interest relative to Smithson, none of which, however, were entirely new. He also procured the following articles:

1. An engraved portrait of Hugh Percy, Duke of Northumberland, father of James Smithson and of Col. Henry Louis Dickinson.

2. A portrait of Henry James Dickinson, son of Col. Henry Louis Dickinson, the nephew and heir of Smithson. (Silhoutte profile.)

3. A paper in the handwriting of James Smithson, a copy of an article by an admiral on the cause of a shipwreck in the English channel.

4. An inventory of the personal effects of James Smithson at the period of his death, made by the British consul at Genoa.

5. An engraved visiting card bearing the inscription: "Henri de la Batut, Hotel Britannique, rue Louis le Grand, 20."

6. Copy in wax of the seal of the de la Batut family.

In addition to its irreparable loss in the death of its late Secretary, the Institution has also to lament that of a number of valued correspondents. Among those to be first mentioned is Mr. Donald Gunn, of Winnipeg, Manitoba, a veteran correspondent of the Smithsonian Institution, one of the earliest of its meteorological observers, and one who for more than twenty years has been a constant contributor of information and collections relating to the natural history of the Northwest.

Mr. Gunn was a Scotchman by birth, and entered the service of the Hudson's Bay Company in 1813; but in 1823 resigned and established himself in the Selkirk settlement in the Red River country, where he was for a long time a successful instructor of youth, and ultimately was appointed one of the judges of the court of petty sessions, holding that position for more than twenty years. He was also a member of the first legislative council of Manitoba, in 1871.

As stated, the first connection of Mr. Gunn with the Smithsonian

Institution was that of a meteorological observer. His long-continued observations of the weather are among the most reliable of those within its archives. His contributions of objects of natural history were still more important, embracing, as they did, nearly every branch in the various classes of the animal and vegetable kingdoms, and numerous collections in archæology and ethnology. Few reports of the Institution since 1850 are without some reference to his services.

In 1866 he made a special exploration, in behalf of the Institution, of the region west of Lake Winnipeg, spending considerable time in the vicinity of Shoal Lake and Lake Manitoba, in the course of which he collected large numbers of skins and eggs of birds; among the latter, several previously entirely unknown in museums. Within a year correspondence was in progress with him in regard to the renewal of this exploration.

The death of Mr. Gunn took place in the month of December, at the age of 81. It is understood that he has left behind him a minutely detailed journal of his experiences, and his relations to the colony in which he lived for over fifty years, which will doubtless be published on account of its great historical value.

Hon. William McKinley, a valued correspondent of the Institution, who died on the 2d of May, 1878, was born in Abbeville District, South Carolina, in the year 1809; became a resident of Georgia in early life; was educated at Franklin College, now the University of Georgia, where he was graduated; entered the profession of law, served as a member of the Georgia legislature; removed to Milledgeville, Ga., where he spent the remainder of his long and useful life in the active and extensive practice of his profession. He sought relaxation in other pursuits at times, none of which were more pleasing to him than the ethnological researches connected with that region, so rich in antiquarian remains, in which his life was spent. He made, within the last few years, repeated contributions of aboriginal remains to the Smithsonian Institution, remarkable for their beauty and value. Mr. McKinley also contributed a valuable paper entitled "Mounds in Georgia" descriptive of aboriginal earthworks on the sea-coast, and of the celebrated Pyramid of Kolee Mokee in Early County, to the Smithsonian Report for 1872. Further additions of antiquities by Mr. McKinley are mentioned on page 82 of the Smithsonian Report of 1875; and at the time of his death, a still later collection was in his possession, destined for the Smithsonian Institution.

Respectfully submitted.

SPENCER F. BAIRD,
Secretary Smithsonian Institution.

WASHINGTON, *January*, 1879.

APPENDIX TO THE REPORT OF THE SECRETARY.

GOVERNMENT EXPLORATIONS AND SURVEYS IN 1878.

The following are brief accounts of the principal explorations of the government in 1878, from which specimens will be derived for increasing the collections of the National Museum. They are furnished by the several directors of the explorations:

THE WORK OF THE UNITED STATES GEOLOGICAL AND GEOGRAPHICAL SURVEY OF THE TERRITORIES UNDER THE DIRECTION OF PROF. F. V. HAYDEN DURING THE SEASON OF 1878.

The work of the survey was intrusted to four parties, viz: One for carrying on the primary triangulation; two parties for geologic and topographic work; and a party for special geologic studies and photography. These were so organized that in case of necessity they could be divided for special duty. The field headquarters of the survey was at Cheyenne, Wyo., and the outfits and animals were transported via the Union Pacific Railroad to their points of departure.

Geology.—Dr. Hayden, the geologist in charge, accompanied the photographic division, and the route pursued gave him an opportunity to secure a very accurate general knowledge of the geological structure of a large area. The Wind River Range proved one of remarkable interest. It has a trend about northwest and southeast, with a length of about 100 miles. On the west side all the sedimentary belts have been swept away, down to the Archæan, older than the Wahsatch, and the latter formation rests on the Archæan rocks all along the base of the range, seldom inclining more than 5° to 10°. On the east side of the range the seams of sedimentary formations usually known to occur in the northwest are exposed from the Potsdam sandstone, which rests upon the Archæan rocks, to the Cretaceous inclusive.

Along the northwestern portion of the range the Wahsatch Group only is seen for some distance, but as we proceed down the Wind River Valley the formations appear one after the other, until at the lower end the entire series is exposed. The Wind River Range may be regarded as originally a vast anticlinal, of which one side has been entirely denuded of the sedimentary, except the Middle Tertiary. On the same side of the range the morainal deposits and glaciated rocks are shown on a scale such as we have not known in any other portion of the West. Three genuine glaciers were discovered on the east base of Wind River and Frémont Peaks, the first known to exist east of the Pacific coast.

The morainal deposits are also found on a grand scale in the Snake River Valley, on the east side of the Teton Range. The numerous lakes have been the beds of glaciers, and the shores of the lakes are walled with morainal ridges. North of the Teton Mountains the prevailing rocks are of modern volcanic origin, and in the Yellowstone Park the hot springs and geysers are the later manifestations of the intense volcanic activity that once existed. All these interesting features were studied with care, and the results will be elaborated for the twelfth annual report of the survey.

Mr. W. H. Holmes acted as geologist to the second division. The first month of the season he was with the fourth division, which proceeded from Point of Rocks Station northward, along the west side of the Wind River Mountains, and up the Snake River Valley to the Yellowstone Park, where he joined the second division. In the mean time he was engaged in making sketches, panoramic views, and geological sections of the intermediate country, all of which will prove of the highest importance in illustrating the geological structure of this most interesting and complicated region.

The latter part of the summer was spent in making detailed geological examinations in the district that includes the National Park. The greater portion of the park was found to be covered with somewhat uniform flows of the ordinary volcanic rocks. Features of more than ordinary geologic interest occur, however, along the northern border of the park district. Here a small belt, not more than 15 by 30 miles in extent, contains a fair epitome of the geology of the Rocky Mountain region. The whole series of formations from the earliest to the most recent are almost typically developed. The only marked irregularity in the succession of geologic events occurred during the great mountain-building period of the early Tertiary. After that followed a number of inferior oscillations of the surface, during which an extensive series of recent Tertiary and volcanic rocks were deposited. Connecting this period with the present are the deposits of a number of great lakes, which at the present time have their chief representative in Yellowstone Lake.

The formations of the Tertiary period present features of more than ordinary interest. They consist of upward of 5,000 feet of strata which are almost totally made up of fragmentary volcanic products. The whole period seems to have been one of unparalleled volcanic activity, the latter part especially having yielded such immense quantities of ejecta that the strata are almost wholly breccias and conglomerates. These formations are therefore so unlike those of corresponding periods in neighboring provinces that it is almost impossible, considering the absence of both vertebrate and invertebrate remains, to make satisfactory correlations. This difficulty is increased by the fact that these formations have a much greater elevation than those of any of the neighboring basins of the interior or eastern plains districts. They lie in a horizontal position, upon the eroded surfaces of the strata of preceding ages, at an elevation of from 6,000 to 11,500 feet above the sea.

A very extraordinary feature of these rocks is the occurrence of silicified forests which are found *in situ* not only at one horizon but at a great number of horizons throughout a great part of the whole series. Fossil leaves found associated with the silicified forests near the middle of the series indicate the prevalence of a flora very closely related to that of the present time. They belong, according to Professor Lesquereux, to late Miocene or early Pliocene times.

Among the many points of interest in the way of flowed volcanic rocks was the discovery and examination of extensive deposits of obsidian. In one locality upwards of 600 feet of obsidian strata occur, much of which is solid glass; banded, spherulitic, and brecciated varieties are interbedded with the more solid layers. A very extensive collection of these and other volcanic rocks was made.

No workable beds of coal have been found within the park area, nor have any deposits of the precious metals been discovered.

To Dr. A. C. Peale and Mr. J. E. Mushbach was assigned the special investigation of the hot springs and geysers. Owing to the lateness of the season when the park was reached, and the early storms in September, there was comparatively little time for work. About two months were spent by them in mapping and investigating the springs in the Shoshone Basin, Upper and Lower Fire-Hole Basins, Red Mountain Basin, Gibbon's Fork Basin, the Mammoth Hot Springs, and the Mud Springs localities of the Yellowstone River.

Over 1,500 temperatures were recorded, and about 2,500 springs were mapped and notes taken for their description. Special attention was paid to the geysers and notes of their times of eruption and the heights reached by them were taken.

Two of the geyser basins were almost unknown before and had never been described. The Gibbon's Fork Basin presented many features of interest, among which were the numerous varieties of the siliceous deposits, many of them probably new to science. Water from important springs of the principal localities was brought in for future analysis. Notes were taken for mapping the different groups of springs on a large scale, so that hereafter they may enable the tourist to identify the individual springs. Many new geysers were discovered and new points of interest in relation to the old ones obtained.

Large collections of specimens were made and brought east.

The notes of this division of the survey being largely statistical, the complete results of the work cannot be detailed until they are thoroughly worked up.

The following is a summary, by Mr. O. St. John, of the geological work prosecuted in the field assigned to the Wind River division:

The region explored comprises a triangular area extending along the forty-third parallel from Salt River to the Wind River Valley, a distance of about 100 miles. The boundaries on either side converge, uniting near the parallel 43° 45′. It thus includes about half of the Wind River

Range and the continental water-shed north to Togwotee Pass, the Gros Ventre Mountains southeast of Jackson's Basin, and in the southwest the considerable area south of the Grand Cañon of the Snake filled by the southern prolongation of the Snake River Mountains, or what is here known as the Wyoming Range, in which latter quarter the work commenced.

The approach was from the south up the valley of Green River, which forms a considerable basin area in the southern central portion of the district, and which is entirely filled with deposits of the age of the Tertiary. These decline basinwards on the three sides hemmed by the Wyoming, Gros Ventre, and Wind River Mountains, attaining a thickness of several thousand feet.

The northern end of the Wyoming Range was here found to consist of several quite well defined low ridges which reach the maximum of ruggedness in the Carboniferous barrier ridge on the western border along Salt River. To the east of this belt Hoback's River rises in a basin area south of the Gros Ventre Range, which, geologically, is part of the Green River Basin, the water-divide being merely a low ridge composed of the soft arenaceous Tertiary beds. The latter are here unconformably uplifted on the border of the Hoback Cañon ridge, the easternmost of the Wyoming Range, and which is made up of Carboniferous and Mesozoic formations occupying a synclinal, either border of which appears in the monoclinal crests on the east and west sides of this ridge.

A tributary of the Hoback on the west of the cañon ridge flows through a valley which penetrates southwards nearly to the southern border of the district. In this vicinity the western crest of the Hoback Cañon ridge shows an anticlinal structure, the Carboniferous on the west flank being succeeded by the Trias, Jura, and Cretaceous, and finally a heavy series of sandstones and variegated arenaceous shales which probably pertain to the Laramie. The latter stretch across the valley, dipping westwardly, and impinge on the next west-lying mountain ridge, which is also composed of Carboniferous strata, abruptly tilted and faulted, with downthrow on the east. Inclining off the west slope of this ridge the same series of geological formations are met with as mentioned above, the later-formed showing subordinate folds and making up the bulk of the highland to the west which has been carved into a very broken belt by the erosion of the eastern tributaries of John Gray's River and the gorges descending to the Snake. Beyond this nearly the same stratigraphical and structural features recur in the more bulky ridge which occupies the interval extending over to Salt River, viz, westerly dipping Mesozoic and Post-Cretaceous deposits, impinging against the faulted Carboniferous in the ridge on the west.

In the latter region much information was gained relative to the identity in stratigraphical and structural elements that subsist here and in the cluster of mountains culminating in Mount Baird north of the Grand Cañon. The whole region here referred to proved to be exceedingly rough, but with redeeming valley spaces abounding in good grazing, while the hills are quite well wooded with coniferous forests.

The southern flank of the Gros Ventre Mountains was traversed from a point near where the Hoback's Cañon ridge first approaches this range, thence east to the broad depression separating it from the northern portion of the Wind-River Range. In the west the culminating peak rises into a bared Archæan cone, the primal rocks occurring at one or two points farther east, where they have been laid bare in the deeper cañons which all the streams penetrating the mountains from this side have excavated. But for the most part this mountain front is heavily plated with Palæozoic formations, including the Potsdam quartzite, Quebec limestones, the magnesian limestone, and the still heavier series of Carboniferous limestones and sandstones, which latter forms the mass of the eastern portion of the range over to the divide at the head of water flowing into Green River. The Palæozoic rocks have been uplifted into great folds, with abrupt inclination on the southerly flanks, contrasting with long declivities in the opposite direction, on which side the range loses much of its rugged, imposing character. Here and there patches of Mesozoic appear low in the south-side mountain flank, succeeded by the unconformable Tertiary beds descending into the Hoback and Green River Basins. In some of the larger cañon mouths interesting exhibitions of morainal and other glacial phenomena were first met with.

The work in the Wind River Mountains was commenced towards the northern end on the west side, and thence carried southwards, circumstances compelling a rapid march round via South Pass to Camp Brown, from which point the work was prosecuted northwards along the eastern flank of the range.

In the vicinity of Green River Cañon, on the west side of the Wind River Range for a few miles, the outer barrier of the mountains preserves a remnant of the Palæozoic formations. These deposits are very similar to the corresponding formations in the Gros Ventre Mountains, and identical with the much more extensive occurrence of strata of that era on the east side of the range. They have been lifted high up on the mountain with minor undulations, and, as seen from the open basin to the southwest, they have the appearance of curving round the extremity of the range. But the latter appearance was found to be deceptive, the Archæan soon reappearing in the outer slope to the north of Green River Cañon, and thence continuing until all the more ancient rock series is hidden by the Cenozoic and Post-Tertiary accumulations at the northern end of the range.

The brief visit paid to the summit of this portion of the Wind River Mountains afforded what is to the student of American geology a field of greatest interest in the existence here of living glaciers. The snow-fields were found to be much more extensive than was surmised from the distant views of the summit, and the ice-filled gorges, especially on the east side at the sources of Torrey's Creek, presented most interesting examples of many of the associated phenomena connected with the glacier. But compared with their former extent these are but the merest vestiges of the ice masses which flowed down and polished the cañon-walls of all the drainage courses which penetrate the range, and in the amount of glaciation and the piled-up *débris* strewn along the sides of the debouching valleys something like an adequate conception of their former extent and comparatively recent dissipation may be formed.

A few miles south of the cañon of Green River the older sedimentaries have been entirely removed from the mountain border, the Tertiary coming in contact with the bared Archæan rocks. Such are the geologic features to the southern border of the district, and probably, indeed, throughout the west flank to the extreme southern terminus at South Pass.

The eastern flank of this range was found to possess a much more extensive area occupied by the Palæozoic formations, which, for the most part, are simply upraised, forming so many more or less well-marked inclined benches. The most recent of these is composed of the Carboniferous, preceded by the magnesian limestone, Quebec limestone, and primordial quartzites, which lithologically, and in the topographic features molded out of them, bear close resemblance to the west flank of the Téton Mountains. At no point were the Trias and later Mesozoic formations found rising to any considerable elevation on the mountain border; on the contrary their presence marks the boundary between the orographic and basin areas. The latter formations present in a general way typical lithologic features characterizing their occurrence in the region to the west, with however many and in some respects somewhat strongly contrasted local stratigraphic peculiarities. The "red beds" of the Trias exhibit enormous local accumulations of massive and laminated gypsum, and the Cretaceous here contains seams of coal which will become of economic value.

In the Wind River Basin the unconformable Tertiary occupies the interval reaching over to the Owl Creek Mountains to the northeast. The border of this basin along the foot of the Wind River Mountains presents some extraordinary spring deposits of very modern date in places incorporated with the gravel deposits occurring in terraces at the foot of the mountains. Many, perhaps the majority, of the spring sources have become extinct; but a few remain, evidently but feeble as compared with their former volume, but which have built up quite extensive deposits of calcareous tufa. Some of the older deposits present much the appearance of porous limestones forming extensive benches in the mountain's foot. The presence of these deposits in some of the cañons on this side of the mountains is associated with the most picturesque scenery. All the streams that rise high up in the mountains were formerly the beds of extensive glaciers which built up the great morainal ridges, like those which border the debouchures of the Little

Wind River, Bull Lake, Dinwiddie, and Torrey's Forks, only less extensive accumulations of glacial materials than those found along the west border of the range.

In the water-shed extending northward from the northern end of the Wind River Range extensive arenaceous deposits of modern-looking Tertiary age but slightly disturbed, are met with, and which evidently form uninterrupted connection with the Wind River Tertiaries on the one hand and the deposits which occupy so large area east of Jackson's Basin on the other. In the latter quarter, in the Mount Leidy highlands, and along the upper courses of the main tributaries of the Gros Ventre, in lower strata of the same series, extensive developments of lignite were met with, the special investigation of which was undertaken by Mr. Perry. In still more ancient horizons other lignitic seams were found which, together with those just mentioned, render this one of the most important coal-producing areas as yet discovered in this region.

In the latter region the lignitic and older mesozoic formations within a narrow belt at the northern foot of the Gros Ventre Mountains have been thrown into a series of sharp parallel folds. To the northeast the Tertiaries dip, with gradually slackening inclination, until they pass beneath the volcanic mantle in the vicinity of Togwotee Pass; on the opposite side the older Mesozoics as uniformly rise up on the flank of the Gros Ventre Mountains, whose northern crest reveals the regular courses of the Carboniferous limestone which in places preserves a coping of the Triassic "red beds."

During the last two months the expedition encountered much inclement weather, embarrassing the prosecution of the field-work; and on its arrival in the region of Mount Leidy and Buffalo Fork, about the middle of October, it was overtaken by the early snows of winter, which virtually closed the field-work for the season.

Paleontology.—So large an amount of paleontological material had accumulated during the previous years that its critical study became necessary for the purpose of aiding in the elucidation of certain problems in structural geology which had arisen in the prosecution of the field-work. Dr. C. A. White, paleontologist to the survey, therefore devoted the whole season of 1878 to this work at the office, instead of taking the field as he did the previous season. The work which thus engaged his attention embraces the preparation of a detailed report of his fieldwork for 1877, including the discussion of important questions connected with it, the preparation of a large number of new fossil invertebrates for publication and illustration, and the illustration of all the types of species in the collections of the survey which the late Mr. F. B. Meek had described, but not illustrated.

Besides the collections made by the various parties of the survey, others have from time to time been received from several persons not officially connected with it, from different parts of the western portion of the national domain. The investigation of these collections brings out some interesting facts concerning the geographical distribution of types, especially those of marine Cretaceous invertebrates. Among the more interesting results of Dr. White's investigations is the recognition of a Triassic fauna in the rocks of Southeastern Idaho. This is of especial interest as being the first discovery of distinctively Triassic invertebrate types in the West, east of those now well known to exist in the Pacific coast region; and also on account of the close relationship of these types with those of the Middle Trias of Europe, while those of the Pacific coast represent the Upper Trias.

Primary triangulation.—The primary triangulation of 1878 was extended northward from that of 1877 which was begun at Rawlins, Wyo., where it connected with the system of triangulation of the survey of the fortieth parallel.

The triangulation party, in charge of Mr. A. D. Wilson, left the Union Pacific Railroad at Point of Rocks, Wyo., on July 28. They traveled northward to the western base of Wind River Range, where their work began. In this range two stations were made, on Wind River and Frémont's Peaks.

Traveling westward from the base of this range, they crossed the head of Green River Basin, and, threading the cañon of Hoback's River, they reached the Snake at the head of its cañon.

They followed this stream up to the eastern base of the Grand Téton, where, finding it impracticable to ascend this mountain from the east, they crossed to Pierre's Hole by way of the Téton Pass. From this, the west side, the peak was found to be more accessible, and Mr. Wilson succeeded in reaching, with his instruments, a secondary summit 100 to 200 feet lower than the main crest, and distant from it about 400 feet. He reported the true summit to be practically inaccessible.

From Pierre's Hole the party next went northwest to Sawtelle's Peak, near Henry's Lake, in Eastern Idaho. On the night following the ascent of this mountain, all the animals belonging to the party were stolen by Bannock Indians, leaving the party afoot, at least 100 miles from the nearest settlement.

After carefully caching their instruments, the party made their way on foot across arid plateaus to the Geyser Basins, where they met the parties of Messrs. Gannett and Jackson. With their aid, and the kind assistance of Mr. James Eccles, an English gentleman who, with a party of his own, was visiting the country, Mr. Wilson was again fitted out, his instruments having in the mean time been recovered, and his work went on with but little delay.

His next station was Mount Sheridan, the highest peak of the Red Mountains, in the southern part of the Yellowstone National Park. Thence he visited Electric Peak, near the northern boundary of the park, and the highest summit within its limits. The well-known Mount Washburn was his next station, and from that mountain he went southward, passing around Yellowstone Lake and up the Upper Yellowstone, intending to make a station on a high peak of the Yellowstone Range, near the head of the latter stream. The snow, however, which had been accumulating for a month in that high mountain region, had become at that time (about the end of September) so deep that it was impossible to do any more work. Indeed, it had accumulated so in the passes about the heads of the Upper Yellowstone, Snake, and Wind Rivers, that the party found difficulty in getting their animals over them. Finally, however, the party reached the head of Wind River, and thence traveled to Rawlins, Wyo., on the Union Pacific Railroad, where they were disbanded.

Topography.—To the party in charge of Mr. Henry Gannett was intrusted the work of making a detailed survey of the Yellowstone Park, with extended study of the phenomena of the hot springs and geysers. Mr. W. H. Holmes was detailed as geologist of this division, while to Dr. A. C. Peale was intrusted the study of the hot springs and geysers, Mr. Gannett undertaking the secondary triangulation and topography of the park, and his assistant, Mr. J. E. Mushbach, the detailed survey of the geyser basins and other groups of springs.

The party left Granger Station, Wyo., on July 28; drove up Green River to the head of the basin; thence down the rugged defile of Hoback's River to the Snake, and up the Snake to its forks at the south boundary of the Yellowstone Park.

Turning westward at this point, they spent a few days in surveying Fall River and its affluents, then returned to the Shoshone Geyser Basin at the west end of Shoshone Lake. Here the party was joined by Mr. Holmes, who up to that time had accompanied Dr. Hayden in the Wind River and Téton Mountains.

Leaving the body of the party in permanent camp at the Shoshone Geyser Basin, Messrs. Holmes and Gannett visited the Red Mountains and the country south of Yellowstone Lake. On their return from this trip, which occupied a week, the party, re-enforced by that of Mr. Jackson, moved across the divide to the Upper Geyser Basin, near the head of the Madison (Fire Hole) River. Here Dr. Peale and Mr. Mushbach were left to carry on their work, while the party continued on down the Fire Hole River to the Lower Geyser Basin. Thence they crossed to the Yellowstone River via Howard's road, and continued down that river to the Mammoth Hot Springs on Gardiner's River, where the supplies for the season were stored.

Refitted with provisions, the party returned up the Yellowstone as far as the mouth of its east fork, which they ascended nearly to its head in the rugged Yellowstone Range; then crossed a high, rolling divide to Pelican Creek, a tributary to Yellowstone Lake. Following this stream down they reached Yellowstone Lake at its northeastern corner, skirted its eastern shore to its head, and traveled several miles up the Upper Yellowstone River; thence they returned to the foot of the lake and followed the river down to the Mammoth Hot Springs, arriving there about October first.

Starting a second time from the springs, the party traveled southward to the headwaters of Gardiner's River and Gibbon's Fork of the Fire Hole, following the road recently cut by Colonel Norris, superintendent of the Yellowstone National Park, from the Mammoth Springs to the Geyser Basins. Having completed their work in this direction, they spent a few days in studying the south end of the Gallatin Range, which separates the waters of the Yellowstone from those of the Gallatin, and then returned to the Mammoth Springs; whence, having been joined by Messrs. Peale and Mushbach, they went to Bozeman, Mont., where the party disbanded.

The above is a sketch of the route of travel of the party. From it the geologist and topographer branched off widely, thus covering the country between the routes of travel.

The area embraced in this survey is about 3,500 square miles, of which material for a map on a scale of one mile to an inch was secured. In prosecution of the work of secondary triangulation and topography 47 stations were made, from which 2,100 horizontal and 500 vertical angles were measured. Altogether 370 points were located, an average of 1 in 9½ square miles; 230 observations for height were made with the mercurial barometer, and 100 with the aneroid.

Material for maps in detail of all localities of special interest was collected. Among these may be mentioned the well-known Geyser Basins, on the Fire Hole, the Shoshone Geyser Basin, the fine group of springs at Heart Lake, and those on Gibbon's Fork discovered by Colonel Norris, the Mammoth Springs on Gardiner's River, the Mud Geysers on the Yellowstone, and others. The heights of all important waterfalls were determined by measurement with the tape-line, and thus the vexed question of the height of the Yellowstone Lower Falls was definitely settled.

The area occupied by the Yellowstone Park has a great elevation, ranging in the flat country from 6,500 feet to 9,000, while its mountain peaks reach heights of 11,000 feet. Its mean elevation is about 8,000 feet. Within this elevated region head three large rivers, the Madison and Yellowstone, which flow off northward to join the Missouri, and the Snake, or Lewis Fork of the Columbia, which at first has a southerly course. The greater part of the Park is a rolling plateau, broken here and there by small groups of mountains, as the Red Mountains and the Washburn Group. East of the Yellowstone River, separating its drainage from that of the Big Horn, is a high, rugged, volcanic range, whose peaks reach 11,000 to 12,000 feet. This range was, in 1871, named "Yellowstone Range" by Dr. Hayden.

Excepting a narrow belt in the northern part, this park is everywhere heavily timbered. Indeed, with the exception of Washington Territory and the western portion of Oregon, it is the most densely timbered area in the West. There is practically no arable land within its limits owing to its great altitude, and, except along its northern border, little open country suitable for pasturage.

The heavy growth of timber indicates and fosters a comparatively moist climate. The park is a region of lakes and swampy tracts, of springs, and abundant perennial streams. The summer season is short. While frosts may be expected any night in the year, the winter holds until June and commences again in September. July and August usually afford fine but cool weather, with cold nights; but September brings frost and snow.

The third division, under Mr. F. A. Clark, surveyed the Wind River Mountains, a portion of the Wyoming Range, the Gros Ventre Range, with a large area in the Snake River Valley. Mr. Clark made 31 gradienter stations and 15 compass stations. The area lies between latitude 43° and 44° and longitude 109° 15′ and 111°. This includes the upper portion of the Wind River Mountains, with portions of the Wyoming Range, the Gros Ventre Range, and portions of the Shoshone Mountains and the Owl Creek Range; also the sources of Green River, Hoback Basin, and upper waters of Wind River. Mr. St. John acted as geologist and Mr. N. W. Perry as mineralogist to this party. Their reports will prove of general interest. Mines of gold, silver, iron, and vast beds of gypsum, as well as many other minerals, were found.

Photography.—In the prosecution of the field-work of the survey during the past season a photographic division was again put in operation, after an interval of two years, under the leadership of Mr. W. H. Jackson, who has been connected with the survey as its photographer during the past nine years.

Leaving Point of Rocks, on the Union Pacific Railroad, on July 24, the first points of interest were reached on the western flank of the Wind River Mountains. Two side trips, undertaken in connection with Mr. Wilson, in charge of the primary triangulation, were made to the crest of the range, and some grand views of that remarkable region were obtained. From the summit of Frémont's Peak views were made of an immense glacier now occupying its eastern slope. Fine views were also obtained of the great glaciated plateau lying between the plains and the crest of the range.

Proceeding next to the vicinity of the Grand Tétons, lying to the east of the headwaters of the Snake River, several magnificent views of the remarkable range in which they occur were made from the neighborhood of Jackson's Lake.

Reaching Shoshone Lake the 18th of August, the entire month following was devoted exclusively to photographing the remarkable phenomena connected with the hot springs and geysers of the various basins within the Park. Especial attention was paid to the almost unknown but exceedingly interesting features of the new Shoshone and Red Mountain Basins. The "Fire Hole" and "Mammoth Hot Spring" Basins were again gone over, and the experience derived from the work done here in former years shows its benefits in the remarkably effective views obtained this season. At this latter basin many detailed as well as general views were made with especial reference to the future production of an exact model in plaster of the whole group.

On the homeward route, which was by the way of the Upper Yellowstone, across the headwaters of the Snake to the Wind River and thence via Camp Brown to the railroad, a number of very effective views were made, particularly about the Grand Falls and the cañon of the Yellowstone. At the Yellowstone Lake some very fine views were made, but that region was not completed, in consequence of a prolonged snow-storm.

At the Togwotee Pass some characteristic views were obtained of the remarkable breccia mountains, whose castellated forms adorn that portion of the continental divide, and also some of the curious "bad lands" farther down on Wind River. The season's work closed at Camp Brown, where portraits and groups were made of the Bannock prisoners in confinement at that post.

A brief summing up of the season's operations of three months, much of which time was characterized by extremely inclement weather, shows an increase to the already very extensive collection of the survey, of 45 negatives 11 by 14 inches in size, and 110 of smaller ones, 5 by 8.

PUBLICATIONS.—During the year 1878 the publications of the United States Geological Survey have been numerous and important, yielding in no respect to those of any previous year, and fully sustaining the reputation this organization has acquired for the prompt and full exhibit of its operations. Eleven separate publications have appeared and others have been brought to a forward state of preparation.

Perhaps the most important of these as a contribution to pure science is the seventh volume of the quarto reports. This is Prof. Leo Lesquereux's beautiful monograph, "The Tertiary Flora," forming a companion volume to the same author's "Cretaceous Flora," which latter constitutes the sixth volume of the series. It consists of nearly 400 pages, and is illustrated with 65 plates.

A further contribution to the fossil flora of the West has been made in the publication of 26 plates, entitled "Illustrations of the Cretaceous and Tertiary Plants of the Western Territories of the United States" This volume consists only of the plates and explanatory text, the full report upon the subject being deferred.

The regular annual report of progress for the year 1876, being the tenth of this series, appeared during the past year. This makes a volume of about 550 pages, illustrated with 79 plates and various woodcuts. There has also been issued in pamphlet form the preliminary report of operations for 1878, in advance of the regular report for that year.

The Miscellaneous Publications' Series has been continued during the year by the issue of Nos. 10 and 11. Miscellaneous Publication No. 10 consists of a Bibliography of North American Invertebrate Paleontology, prepared by Dr. C. A. White and Prof. H. Alleyne Nicholson. Miscellaneous Publication No. 11 is entitled "The Birds of the Colorado Valley," and consists of Part First of an extensive work upon North American Ornithology, by Dr. Elliott Coues, U. S. A. Both these treatises have become indispensable to the students of the special branches of which they respectively treat.

The Bulletins of the survey have appeared during the year with the usual regularity, the four numbers issued in 1878 forming volume IV. This publication is now established as a regular annual serial, and the present volume, like its predecessors, contains articles on a wide range of scientific topics embraced within the general scope of the operations of the survey.

The United States Entomological Commission, conducted under the auspices of this survey, has during the year issued its first annual report, as an octavo volume of nearly 800 pages, with plates and woodcuts. It is devoted to the subject of the Rocky Mountain Locust, and contains a full exhibit of the results secured by the commission appointed to investigate that important problem.

UNITED STATES GEOGRAPHICAL SURVEYS WEST OF THE ONE HUNDREDTH MERIDIAN, IN CHARGE OF FIRST LIEUT. GEORGE M. WHEELER, CORPS OF ENGINEERS, UNITED STATES ARMY.

The work during 1878 was performed by nine main parties and three astronomical parties, which operated in the States of California, Colorado, Nevada, Oregon, and Texas, and Arizona, New Mexico, and Washington Territories. Forty-six observers took the field, leaving a small force at the Washington office engaged in the preparation of maps and reports. The astronomical parties, in charge of Professor T. F. Safford, at the Ogden Observatory, Mr. J. H. Clarke in the California sections, and Mr. Miles Rock in the Colorado section, made observations at Walla-Walla, Washington Territory; the Dalles, Oregon; Fresno, California; Fort Bliss, Texas; and Fort Bayard, New Mexico, connecting with Ogden as the initial meridian.

In California, topographical parties occupied points in the Cascade Mountains and ranges to the eastward within the Great Interior Basin extending towards the Blue Ridge, reconnoitring a large area. Operations were carried southward from Lake Tahoe along the Sierra Nevada, one party occupying the White Mountain Range and connecting with the triangulation which joins the astronomical station at Austin, Nevada. A contour survey of the Washoe mining region was completed, and numerous details gathered relating to the operations of the vertical and meridional sections of the lodes.

Work for completing the topography of the section between Sierra Nevada and Cascade Ranges was also carried on. From the southern end of the Sierra Nevada a party transferred from the Utah section connected with the work of 1875 from Los Angeles east and north, and operated along the Coast Range to latitude 30° 30′ N.

In Colorado, one party, following the Rio Grande northward, filled in details of new routes of communication and of incomplete meanders, and was further employed upon detailed work. A detachment meandered north and westward from the Rio Grande at Los Lanos, opposite Fort McRae, through the basin of the Little Colorado to Camp Apache, Arizona, and thence eastward again to the Rio Grande, making meanders of considerable precision along three natural routes of communication from the drainage basins of the Gila Salt River and Colorado Chiquito to the Rio Grande.

Another party extended the triangulation southward to connect with astronomical station at Fort Bliss, Texas; also connecting with the astronomical monument of the Mexican Boundary Survey at El Paso, Texas, and the monument on that part of the boundary-line on the western bank of the Rio Grande.

The following list shows the number of the principal observations made:

Sextant latitude stations	90
Bases measured	5
Triangles about bases measured	64
Main triangulation stations occupied	62
Secondary triangulation stations occupied	21
Miles measured on meanders	10,298
Cistern barometer stations occupied	1,141
Aneroid barometer stations occupied	7,057
Magnetic variations observed	165
Mining camps visited	12
Mineral and thermal springs noted	20

The estimated area occupied by the survey during the season, including main triangulation and preliminary reconnaissance work, was 35,000 square miles. The area from which detailed topographical data were gathered sufficient for a map, on a scale of one inch to four miles, was approximately 27,500 miles.

Besides the topographical work, one party in the Colorado section was devoted entirely to geological examination, under the charge of Professor J. J. Stevenson, assisted by Mr. J. C. Russell. Its area of operations was along the Spanish ranges between the Rio Grande and Canadian Rivers, in the northern part of New Mexico, where its labors were greatly facilitated by the use of the completed topographical maps. The section of the lignitic group was worked out, and twenty-six beds of lignitic coal were recognized as present at most localities within the area where the horizon was reached. Much labor was bestowed upon a study of the axes, the structure of which was found to be exceedingly complicated, requiring further detailed examination. Quite large collections were made of igneous rocks and fossils, about three hundred specimens of the former being obtained from seventy localities, forming a complete series illustrating the lithology of the injected dikes, volcanic overflows, and extinct craters of the region.

The fossils, numbering over thirteen hundred specimens, are from rocks of the Carboniferous age, from Cretaceous strata, Nos. 2, 3, and 4, and from overlying beds of the Lignitic group.

From the Carboniferous formation, about seven hundred specimens were obtained; from the Cretaceous, five hundred, illustrating its invertebrate fauna; and from the coal-bearing Lignitic group, resting on the black shales of Cretaceous stratum No. 4, about two hundred specimens of fossil leaves.

Zoological collections were mainly made by the party operating from Northern California northward, and illustrate the zoology of the area extending from Camp Bidwell, California, to the Columbia River, Oregon. To this party Mr. H. W. Henshaw was attached as naturalist. The collection made comprises upwards of three hundred specimens of birds, specimens of fishes from most of the lakes and streams encountered, with *Lepidoptera*, *Orthoptera*, and numerous reptiles and Batrachians.

The field season ended early in December. The work of this survey has now covered, since its commencement in 1859, connected areas reaching from the Columbia River on the north to the Mexican border, and from the 100th meridian, near Fort Dodge, to the Pacific Coast, near Los Angeles, an area now exceeding 350,000 square miles.

The publications during the year are as follows: Vol. II, quarto series, Astronomy and Barometric Hypsometry; "A Catalogue of 2,018 Stars, for Latitude Work West of the Mississippi," and ten of the regular atlas-sheets. Vol. VI, quarto series, was in stereotype at the close of 1878; a "List of Distances, Positions, Altitudes," &c., was well advanced in printing; and Vols. I and VII, of the quarto series, awaited the appearance of Vol. VI. Seventeen atlas-sheets, also from work prior to 1878, are in various stages of progress.

GEOGRAPHICAL AND GEOLOGICAL SURVEY OF THE ROCKY MOUNTAIN REGION, BY PROF. J. W. POWELL.

The labors of this survey have been continued during 1878. From the return of the field-parties in the autumn of 1877 till July, 1878, the entire corps remained in Washington, preparing the results of the field-work for publication. In July, 1878, a division was sent to the field, but a force was also retained at Washington to continue the ethnographic work, and to complete and edit certain unfinished reports.

The office-work thus acquired an exceptional importance as compared with the field-work, which, for the season of 1878, was placed in charge of Mr. C. K. Gilbert, his principal assistants being Messrs. J. H. Renshaw, O. D. Wheeler, and S. H. Bodfish.

Taking the field at Gunnison, Utah, in the early part of August, the work was carried on by four independent parties till the middle of December, when the advance of winter made it necessary to disband them.

The Kanab base-line, four and one-third miles long, has been carefully remeasured, with a probable error of 1.5 inches, as well as the southern portion of the chain of triangles connecting it with the Gunnison base-line. The main change of triangulation, consisting of eight quadrilaterals, one triangle, and one pentagon, is now ready for discussion. At each end of the chain a base-line has been measured, and an astronomical determination has been made of latitude, longitude, and azimuth. The most southerly points visited were Mount San Francisco and Mount Floyd, volcanic peaks on the Colorado plateau south of Grand Cañon. Southern Utah is not well adapted for triangulation. Its principal eminences are table-lands or plateaus covered with timber, there being very few sharp peaks readily distinguishable from all directions.

The work of Mr. Renshaw's party, with plane-table and orograph, embraces all of the region lying south of the Grand Cañon in sections 105 and 106, covering about 7,500 square miles. This field comprised a portion of what is known as the Colorado Plateau, a high table-land lying immediately south of the Colorado River, which there runs westwardly at the bottom of a deep chasm. On the southern edge of the plateau there are innumerable extinct volcanoes, the ground being covered by a forest of pine, the most valuable tract of timber in Arizona. The northern edge is lower, and is bare of timber. Near the Colorado Cañon it is broken by gorges, and is difficult of access, but in other directions there is little impediment to travel. Water is scarce, and is found only in pockets and small springs, there being none available for irrigation. The only wealth of the country lies in timber and grass. West of the plateau, Mr. Renshaw's map includes a portion of Hualapai Valley and the adjacent mountains. This region is almost an absolute desert, water being so scarce that in some places it is sold by the gallon. Agriculture is out of the question, and there is no timber. Grazing is practicable to a limited extent. The only important industry, present or prospective, is mining, and only the richest of the numerous gold and silver deposits can now be worked with profit, owing to the remoteness of all sources of supplies.

Mr. Wheeler worked with plane-table and orograph in the western half of the region comprised by atlas-sheet No. 106, and estimates his total area at 5,000 square miles. Through the centre of his district there runs from north to south a natural barrier called the Echo Cliff. The escarpment faces westward, and the plateau at the west of it is 1,000 feet lower than that to the eastward. The eastern plateau is a broad desert of sand, scantily watered, and useful only for grazing purposes. The western plateau is equally barren and worthless, but presents more variety of surface. A portion consists of naked "bad lands," soft strata carved by the elements into hills of picturesque beauty, and tinted with a variety of brilliant colors which warrant the title of Painted Desert, bestowed by Lieutenant Ives. Another portion is extremely rocky, and divided by a net-work of impassable cañons. Through this region runs the Little Colorado River, a stream of considerable magnitude, but, on account of the character of its banks, of no service to agriculture. Echo Cliff is interrupted at one point by a cross-line of drainage, and there are a few springs available for farming. No other spot invites settlement. Maps, on a scale of four miles to one inch, show the geography of the entire region embraced in the survey of Major Powell; a map is also under construction intended to represent the distribution of the various tribes of Indians when first discovered by Europeans.

Table showing the number of entries in the record-books of the United States National Museum at the close of the years 1877 *and* 1878, *respectively.*

Class.	1877.	1878.
Mammals	12,838	13,069
Birds	17,523	76,666
Reptiles and amphibians	9,500	10,015
Fishes	20,864	22,000
Skeletons and skulls	15,877	16,155
Eggs	17,500	17,791
Crustaceans	2,324	2,324
Annelids	100	100
Mollusks	30,721	31,268
Radiates	3,229	3,230
Invertebrate fossils	7,906	8,020
Minerals	20,135	20,135
Ethnological specimens	30,883	34,600
Total	245,400	255,373
Increase for 1878	....	9,973

Approximate table of the distribution of duplicate specimens to the end of 1878.

Class.	Total to the end of 1877.		Distribution during 1878.		Total to the end of 1878.	
	Species.	Specimens.	Species.	Specimens.	Species.	Specimens.
Skeletons and skulls	536	1,818	4	60	540	1,878
Mammals	2,159	4,810	8	12	2,167	4,822
Birds	27,594	41,866	123	148	27,717	42,014
Reptiles	2,135	3,488	221	352	2,356	3,840
Fishes	6,140	9,645	5	6	6,145	9,651
Nests and eggs of birds	7,639	18,746	267	604	7,906	19,350
Insects	4,209	9,500	99	241	4,308	9,741
Crustaceans	1,089	2,664	0	0	1,087	2,664
Shells	90,171	196,443	377	904	90,548	197,347
Radiates	593	793	0	0	593	793
Other marine invertebrates	1,892	5,225	0	0	1,892	5,225
Plants and packages of seeds	29,437	50,969	506	1,015	29,943	51,984
Fossils	4,361	10,468	30	50	4,391	10,518
Minerals and rocks	9,104	16,868	1	1	9,105	16,869
Ethnological specimens	2,234	2,681	1,389	2,587	3,623	5,268
Diatomaceous earths (packages)	428	1,182	446	446	874	1,628
Total	189,719	377,166	3,476	6,426	193,195	383,592

ADDITIONS TO THE COLLECTIONS OF THE NATIONAL MUSEUM IN 1878.

Akron (Ohio) City Museum. Eighteen species of fresh-water *Unios;* from Ohio.

Albro, Samuel (through Hon. Samuel Powel). Fish (*Pseudopriacanthus altus*); from Newport, R. I.

Aldrich, Charles. Collections of living snakes, turtles, and frogs; and specimens of Indian relics; from Iowa.

Alexander, James H. Box of ethnological and mineralogical specimens; from New York.

Allen, Charles A. Collection of birds' eggs and nests, and six living turtles; from California.

Allen, Charles S. Collection of birds' skins and eggs; from Long Island, N. Y.

Allen, George K. (See Washington, D. C., United States Fish Commission.)

Anderson, Capt. Chris. (See Washington, D. C., United States Fish Commission.)

Anderson, E. J. Salmon (*Salmo salar*); from the Delaware River.

Anderson, William. Six stone implements; from Illinois.

Andrews, Frank D. Eight rude arrow-heads; from New Jersey.

Andrews, F. S. (See Washington, D. C., United States Fish Commission.)

Artes, Charles F. Photographs and drawings of Indian relics, and relics from mounds in Illinois.

Armistead, E. P. Ball of hair taken from stomach of cow.

Atkins, Charles G. Three boxes of fishes; from Bucksport and Grand Lake Stream, Maine.

Atkinson, John. (See Washington, D. C., United States Fish Commission.)

Babcock, A. L. Six birds' skins; from Massachusetts.

Babson, Fitz J. (See Washington, D. C., United States Fish Commission.)

Babson, Fitz J., jr. (See Washington, D. C., United States Fish Commission.)

Babson, William H. (See Washington, D. C., United States Fish Commission.)

Baird, Prof. S. F. Five gudgeons (*Hybognathus regius*), from Babcock Lake; three terrapins, from the Susquehanna River.

Baker, Captain. (See Washington, D. C., United States Fish Commission.)

Banta, W. V. and J. Garrison. Bones of human skeleton; taken from Indian mound at Salem, Iowa.

Barber, E. A. Articles of Indian ornament, from Arizona and Utah; marine animals and Indian stone relics, from New Jersey, Pennsylvania, and Maryland.

Barker, Dr. S. W. Mud-eel (*Siren lacertina*); from Charleston, S. C.

Barth, Henry. Mineral; from Maryland.

Bartlett, A. (See Washington, D. C., United States Fish Commission.)

Bassett, L. Stone axe; from Iowa.

Bates, James. (See Washington, D. C., United States Fish Commission.)

Bausett, William A. (See Washington, D. C., United States Fish Commission.)

Bean, Dr. T. H. Collection of stone implements, from Eastern Pennsylvania; collection of frogs, snakes, lizards, and fishes, from Prince George's County, Maryland; four specimens of fish, from Norfolk, Va.

Beardsley, Grant. Stag-beetle (*Cerphus elephas*); from North Carolina.

Beauchamp, Rev. W. M. Five stone implements; from New York.

Beckwith, Harney. (See King's Mountain Mine.)

Belding, L. Seven boxes of birds' skins and twelve Indian relics; from California.

Bell, William. Specimen of iron pyrites; from Virginia.

Bellamy, Frank H. Box of fragmentary erennite stems, from Alabama; Indian relics, from Alabama and North Carolina.

Bendire, Capt. Charles, U. S. A. Nest and eggs of *Passerella townsendii* var. *schistacea*, and Clark's crow, also box of birds' skins; from Oregon.

Benner, D. B. Squeezed copy of rock inscription and Indian relics; from Virginia.

Berlin, A. F. Collections of stone implements; from Reading, Pa.

Bernays, Lewis A. Photographs of mummies found in forks of trees, Queensland, Australia.

Berry, Henry. Steel dagger used by Wisconsin Indians.

Biddle, Henry J. Box of relics exhumed from mound in Florida.

Bigelow, O. Stone implement; from New York.

Blackburn, Capt. William. (See Washington, D. C., United States Fish Commission.)

Blackford, E. G. Many specimens of fish (salmon, cod, trout, shad, &c.), brought to Fulton Market, New York, from various parts of the United States.

Blackly, C. P. Mounted specimen of American eared grebe (*Podiceps auritus* var. *californicus*); from Kansas.

Blake, Capt. J. G., U. S. R. M. Specimen of *Remora;* from Rhode Island.

Bland, Thomas. Specimens of shells (*Bulimus, Pagurus*, and *Lignus*); from Tobago and Gonaive Islands.

Blatchford, Capt. B. F. (See Washington, D. C., United States Fish Commission.)

Boardman, George A. Specimens of spotted ury-mouth (*Cryptacanthodes maculatus*) and stickleback (*Gasterosteus biaculeatus*); from Calais, Maine.

Boehmer, George H. Collection of "fossil-casts," from Maryland; specimen of itacolumite, from North Carolina.

Bomar, Thomas H. Snakes (*Ophibolus getulus, Crotalus miliaris*) and arrow-heads; from South Carolina.

Boston, Mrs. C. B. Box of shells; from Illinois.

Brace, Lewis J. K. Box of birds from the Bahama Islands. (Received in 1877.)

Brackett, Col. A. G., U. S. A. Head of eel-pout, from Little Big Horn River, Montana; specimen of field-mouse (*Arvicola*), from Montana.

Brady, Samuel. Copper spear and barrel of stone mining-hammers; from Michigan.

Braner, William. Collection of copper and flint arrow-heads; from Wisconsin.

Brazier, Benjamin S. (See Washington, D. C., United States Fish Commission.)

Breed, E. E. Nest of "carpenter-bee."

Braîon, Fred. Specimens of arrow-heads, &c.; from West Virginia and Indiana.

Brewer, Dr. T. M. Egg of Clarke's crow.

Brewster, William. Five skins of *Sitta pusilla.*

Briggs, Captain. (See Washington, D. C., United States Fish Commission.)

Brisbane. (See *Queensland.*)

Britt, Thomas A. Collection of Florida shells.

Brock, R. A. Cocoons of *Cecropia* silk-work; from Virginia.

Brodnax, Benjamin H., M. D. A fine collection of stone axes, spear and arrow heads, hematite plummets, &c.; from Louisiana.

Brown, Dr. J. J. Specimen of coral (*Diploaria cerebriformis*); from Nassau, N. P.

Brown, Stephen S. Sample of "Nicaragua" wheat; from Waco, Texas.

Brown, William. (See Washington, D. C., United States Fish Commission.)

Bryan, Oliver N. Box of rude stone implements; from Maryland.

Burbank, Martin. (See Washington, D. C., United States Fish Commission.)

Burger, Peter. Carolina rail (*Porzana carolinensis*); from Virginia.

Burke, Henry E. (See Washington, D. C., United States Fish Commission.)

Burnes, B. J. Specimen of *samarskite;* from Alabama.

Burns, Thomas. (See Washington, D. C., United States Fish Commission.)

Bullock, Theron. Copper nodule; from Wisconsin.

Butler, Isaac. (See Washington, D. C., United States Fish Commission.)

Cadle, C. Indian pipe of micaceous sandstone; from the east shore of Mobile Bay, Alabama.

Calderwood, Capt. M. W. (See Washington, D. C., United States Fish Commission.)

Cambridge, Mass., Botanic Garden of Harvard University, C. S. Sargent, Director. Seeds and plants of aquatic plants (*Nymphæa tuberosa, Rumex hydrolapatum*, &c.).

Cambridge, Mass., Museum of Comparative Zoology. Box of birds' skins, box of alcoholic specimens of general natural history, and specimen of menhaden (*Brevoortia aurea*).

Campbell, J. B. Specimens of reptiles, turtles, and batrachians; from Iowa.

Campbell, Kent. Nest and eggs of wood pewee (*Contopus virens*); from Ohio.

Capehart, Dr. W. R. Specimens of shad and herring; from Avoca, N. C.

Capron, John. (See Washington, D. C., United States Fish Commission.)

Capron, General Horace. Two dressed figures representing the noble class of Japan. (Purchased.)

Chappell & Storer (through E. G. Blackford). Large number of *Trachurops crumenophthalmus.*

Carlsen, Arnold. (See Washington, D. C., United States Fish Commission.)

Carritt, William. (See Washington, D. C., United States Fish Commission.)

Carroll, Capt. Daniel. (See Washington, D. C., United States Fish Commission.)

Case, Thomas S. Specimen of *Lota maculosa;* from Missouri.

Cavener, Nicholas. (See Washington, D. C., United States Fish Commission.)

Chester, H. C. Jar of fishes, from the Potomac River; model of codfish hatching apparatus.

Chicago Academy of Science. Collection of shells; from Florida.

Childs, Edward R. (See Washington, D. C., United States Fish Commission.)

Churchill, R. C. Malformed robin (*Turdus migratorius*); from New York.

Clark, Benjamin. (See Washington, D. C., United States Fish Commission.)

Clark, Frank N. Water-snake; from Spesutia Island, Maryland.

Clark, Samuel C. "Mule-killer" (*Thelyphonus gigantens*), from Florida; arrow-heads and fragmentary pottery, from Georgia.

Clarke, Prof. F. L. Box of ethnological and natural-history specimens; from Hawaii.

Clarke, J. H. Box of fossils (fishes, &c.); from Connecticut.

Clarke, Dr. W. M. Mica arrow-head and shell; from mound in Tennessee.

Clinton, Capt. George T. (See Washington, D. C., United States Fish Commission.)

Coast Wrecking Company, New York (through W. R. T. Jones). Specimen of marble bored by sponge (*Cliona*); taken from the wreck of the steamer Grecian off Long Island.

Colby, Charles. (See Washington, D. C., United States Fish Commission.)

Cole, J. R. Iron pyrites; from Texas.

Collins, Capt. Joseph W. (See Washington, D. C., United States Fish Commission.)

Collins, William. (See Washington, D. C., United States Fish Commission.)

Compton, J. W. Larvæ of *Helophilas anax*; from North Carolina.

Conley, John. (See Washington, D. C., United States Fish Commission.)

Conrad, L. Specimen of mineral; from Ohio.

Cook, Caleb. Two bottles of fish-oil.

Cook, D. S. Stone sinker and axe; from Pennsylvania.

Cooper, William A. Skin of *Ptychorhamphus aleuticus;* from Santa Cruz, Cal.

Cope, Prof. E. D. Two living lizards (*Crotaphytus collaris*); from Texas.

Coster, John. Small stone axe; from Wisconsin.

Crawford, General S. W. Box of geological specimens and birds; from Iceland.

Cressy, Charles C. (See Washington, D. C., United States Fish Commission.)

Crittenden, A. R. Three boxes of Indian relics; from the New England States.

Crooke, John J., New York, N. Y. Twenty-five pounds of pure tin.

Cunningham & Thompson. (See Washington, D. C., United States Fish Commission.)

Curle, Dr. T. J. Hair-worm (*Gordius*); from Kentucky.

Curtis, Captain. (See Washington, D. C., United States Fish Commission.)

Cushing, Frank H. Collections of rude potstone vessels, from Virginia and District of Columbia; living reptiles, from Virginia.

Cuvier Club, Cincinnati, Ohio. Collection of bird-skins, from Indiana, Ohio, and Florida.

Dall, W. H. Four specimens illustrative of the economic application of shells; two marine shells from Japan; two land shells from Germany.

Dalrymple, Dr. Specimens of Indian pottery; from Maryland.

Danforth, John. (See Washington, D. C., United States Fish Commission.)

Davis, Mrs. Abby L. (See Washington, D. C., United States Fish Commission.)

Davis, Capt. Alfred B., U. S. R. M. Specimen of coral; from the Dry Tortugas, Florida.

Davis, Henry. Samples of soil and wood; from McGregor, Indiana.

Davis, Joshua. Indian chunky-stone; from District of Columbia.

Davis, L. Specimen of iron ore; from Missouri.

Davis, M. C. Specimen of iron ore; from Harper's Ferry.

Davis, Mrs. Mary E. (See Washington, D. C., United States Fish Commission.)

Day, Thomas, Keeper of Seguin Light, Maine. Three fish-hooks.

De Hart, J. N. Box of Indian bones and relics; from mound in Illinois.

Dempsey, Capt. William. (See Washington, D. C., United States Fish Commission.)

Dennis, George R. Box of sea-weed and *Trichiurus lepturus;* from Maryland.

Denton, Shelley W. Eggs of burrowing owl; from Fort Collins, Colorado.

Devan, James. (See Washington, D. C., United States Fish Commission.)

Devoe, Capt. Luke. (See Washington, D. C., United States Fish Commission.)

Dexter, Newton. Eggs of *Phæton flavicauda;* from Bermuda.

Dixon, Eugene F. (See Washington, D. C., United States Fish Commission.)

Dixon, Capt. Geo. W. (See Washington, D. C., United States Fish Commission.)

Doran, Thomas S. Specimens of turtles and fish; from Montgomery, Ala.

Douglas, W. T. Insect; from Catlett's, Va.

Douglass, John. (See Washington, D. C., United States Fish Commission.)

Douglass, Robert, 2d. (See Washington, D. C., United States Fish Commission.)

Driggs, John W. Collection of birds' skins; from Florida.

Driscoll, Daniel. (See Washington, D. C., United States Fish Commission.)

Duffield, U. S. G. Malformed eggs of common hen.

Dugès, Dr. Don Alfredo. Box of natural history specimens; from Guanajuato, Mexico.

Dulaney, John. (See Washington, D. C., United States Fish Commission.)

Duncan, Capt. J. F. (See Washington, D. C., United States Fish Commission.)

Earle, T. L. Small box of minerals; from North Carolina.

Edwards, Vinal N. Eleven boxes of fishes collected in Vineyard Sound, Massachusetts.

Eggert, H. Four living turtles; from Missouri.

Ellis, Albert N. Specimens of snakes; from Florida.

Ellis, J. B. Collection of North American fungi.

Espersen, Henry, Surveyor-General of Dakota. Two packages of minerals; from Dakota.

Etzel, C. Stone axe; from Wisconsin.

Evans, Samuel B. Four stone implements, from Iowa; casts of stone axe and pipe from Kansas.

Evans, W. W. A large collection of pottery, silver and copper idols, bronze implement, and egg of emu; from Peru. Also, 27 sheets of photographs of Peruvian antiquities.

Ferguson, Mr. (through O. C. Treadway). Specimens of minerals; from Big Sioux River, Iowa.

Finsch, Dr. Otto. Twelve species of Siberian fishes.

Firth, William A. Three samples of diatomaceous earths; from Ireland.

Flanagan, A. H. Collection of stone implements and pottery, and human and animal bones; from a mound in Virginia.

Flint, Dr. Earl. Two boxes of fossils and alcoholic specimens; two boxes ethnological specimens; from Nicaragua.

Floyd, Joseph D. (See Washington, D. C., United States Fish Commission.)

Fox, F. N. (through Rev. J. J. McCook). Rough stone axe-head, fragment of celt, and fragment of pottery; from Niantic, Conn.

Foster, Mrs. Abner. Box of stone implements; from Illinois.

France, Museum of Natural History. Collection of fishes from the Mediterranean Sea and rivers of France.

Frazer, Charles. Pottery figure; from Botica, Puerto Plata.

French, S. Levin. Four boxes of "American sardines."

Friend, Sidney. (See Washington, D. C., United States Fish Commission.)

Gaffney, William M. (See Washington, D. C., United States Fish Commission.)

Gaines, A. S., and K. M. Cunningham. Terra-cotta mask; from vicinity of Mobile, Ala.

Galbraith, F. G. Four boxes of stone implements, collection of alcoholic fishes, insects, &c., and a small living alligator; from Eastern Pennsylvania.

Garret, W. M. Pottery fragments, spear-head, and quartz crystal; from Alabama.

Gates, D. C. (through Rev. J. J. McCook). Stone chisel; from Niantic, Conn.

Gatschet, A. S. Samples of the food of the Klamath Indians of Oregon.

Gere, J. E. Collection of copper knives, spear and arrow heads, masses of native copper and flint arrow-heads, stone axes, &c.; from Wisconsin.

Germany, Berlin Museum, Dr. E. von Martin. Nine species of shells.

Gerrard, Edward, Jr. Sixteen mounted specimens of English quail, woodcock, and snipe. (Purchased.)

Gessner, William. Collection of Indian arrow-heads, &c.; from Alabama.

Getchell, Capt. John Q. (See Washington, D. C., United States Fish Commission.)

Gibbs, George J. Collection of ethnologica; from Grand Turk, West Indies.

Gibbs, J. D. Three malformed feet of pig.

Gilbert, Rev. C. A. Collection of shells, insects, fossils, &c.; from Florida.

Ginnevan, Thomas, and Philip Merchant. (See Washington, D. C., United States Commission.)

Githens, W. H. Box of shells and casts of Indian relics; from Illinois.

Godding, Dr. W. W. Specimen in flesh of bear (*Ursus americanus*).

Goff, George P. "Sea-dollar"; from Galveston, Tex.

Goode, F. C. Collection of living snakes; from Florida.

Goode, G. Brown. Tank of alcoholic fishes and three boxes living snakes and turtles, from Florida; box of fishes, corals, &c., from Charleston, S. C.; three cans alcoholic fishes, from Bermuda. Also, fresh specimens of shad, from the St. John's River, Florida.

Goodrich, Wilbur F. Specimens of fungi; from Massachusetts.

Goodwin, Thomas. (See Washington, D. C., United States Fish Commission.)

Gore, H. Specimen of ore; from Pennsylvania.

Gorton, Slade & Co. (See Washington, D. C., United States Fish Commission.)

Goslin, Capt. Joseph. (See Washington, D. C., United States Fish Commission.)

Goss, N. S. Skin of *Parus atricapillus*; from Wisconsin.

Gourville, Capt. John. (See Washington, D. C., United States Fish Commission.)

Green, F. C. Box of stone implements and collection of minerals; from Wisconsin.

Green, Dr. Samuel A. Cast of Indian pot found at Canterbury, N. H.

Greenleaf, Capt. William H. (See Washington, D. C., United States Fish Commission.)

Griffith, William. Two roe-shad; from the Ohio River.

Grüber, Ferdinand. Two living turtles (*Chelopus marmoratus*); from California.

Gunnan, Miss Bessie C. Scale of tarpum (*Megalops thrissoides*); from near Norfolk, Va.

Hallock, Charles. Specimen of *Coregonus quadrilateralis*; from Michigan.

Hamlen, Capt. Peter. (See Washington, D. C., United States Fish Commission.)

Hardenburgh, A. R., United States Surveyor-General, California. Collection of the ores of various mines in California.

Harker, O. H. Collection of minerals; from Colorado.

Harris, R. S. Specimen of *itacolumite*; from North Carolina.

Hartsfield, John M. Skink snake, from North Carolina; and eggs of white-eyed flycatcher, from Delaware.

Harvey, Edward. (See Washington, D. C., United States Fish Commission.)

Harvey, Rev. M. Alcoholic specimens of capelin; from Newfoundland.

Haskell, Samuel. (See Washington, D. C., United States Fish Commission.)

Haskin, S. D. Flint arrow-head; from Tennessee.

Hawkins, Capt. James. (See Washington, D. C., United States Fish Commission.)

Hawkins, Capt. Z. (See Washington, D. C., United States Fish Commission.)

Harneus, ———, Stockholm, Sweden. Series of manufactured fire-bricks.

Hayward, F. W. Box of rice plants, tank of alcoholic fishes, reptiles, &c., living specimens of mud-puppy (*Siren lacertina*), and living snapping-turtles; from South Carolina.

Haywood, W. P. Two red ants; from New Jersey.

Helper, H. R. (through George Hillier). Saw of sawfish (*Pristis antiquorum*).

Hemphill, Henry. Collection of land and fresh-water shells, from Utah; collection of shells and fossils, from California.

Hempstead, Elias. Box of ethnological specimens; from Santa Rosa Island, Florida.

Henderson, Judge J. G. Box of ethnological specimens; from Illinois.

Henderson, Mr. (through Dr. H. B. Noble). Slate carving; from the Northwest coast of America.

Hendricks, Lindsley. Mineral; from Texas.

Henshaw, H. W. Living turtle (*Cistudo clausa clausa*) and nest and eggs of *Seiurus aurocapillus* and *Turdus mustelinus;* from Washington, D. C.

Hering, Dr. C. J. Collection of alcoholic mammals, reptiles, insects, &c.; from Surinam.

Herring, Richard. (See Washington, D. C., United States Fish Commission.)

Hessel, Rudolph. Two specimens of snake (*Tropidonotus sipedon*); from Baltimore, Md.; and one of *Hyla arborea*, from Germany.

Hewitt, Isaac L. (See Washington, D. C., United States Fish Commission.)

Higbie, A. B., & Co. Specimen of *Tetrodon lævigatus;* from off Cape Henlopen.

Higgins & Gifford. (See Washington, D. C., United States Fish Commission.)

Hillier, Fred. (See Washington, D. C., United States Fish Commission.)

Hirst, F. Specimens of amblystoma and larvæ and fishes (*Potamocottus*), from Utah; and fishes (*Potamocottus, Catostomus*), from Wyoming.

Hitchcock, Prof. E. Casts of Indian vessels.

Hitchcock, George N. Specimens of living turtles; from California.

Hitt, Dr. D. F. Box of fossil plants; from Illinois.

Hodgdon, Capt. T. F. (See Washington, D. C., United States Fish Commission.)

Hodgkins, Edward W. (See Washington, D. C., United States Fish Commission.)

Holbrook, W. C. Flint arrow-head, stalagmite, fossil shell and bone of human foot; from Illinois.

Hollenbush, H. W. Box of minerals; from Pennsylvania.

Homans, Capt. Charles A. (See Washington, D. C., United States Fish Commission.)

Horan, Henry. Turtle (*Chelopus guttatus*); from Washington D. C.

Horod, C. H. Two fossil teeth of horse.

Hough, Dr. F. B. Cast of tusk of fossil elephant, found near Copenhagen, N. Y.

Hoy, Geo. W. (See Washington, D. C., United States Fish Commission.)

Hoy, R. R. Snake (*Coluber*) and turtles (*Chrysemys*); from Michigan.

Hübregtse, A. Three arrow-heads.

Hudson, J. M. Pharyngeal teeth of sheeps-head.

Hughes, W. N. Specimen of fossil coral; from Tennessee.

Hunt, Henry C. Four articles of native dress; from Peru and Bolivia.

Hunt, Capt. H. W. Samples of cordage and duck manufactured by the Russian Government.

Hurlbert, Capt. R. H. (See Washington, D. C., United States Fish Commission.)

Huss, Oscar E. Specimens of woods, teas, and ethnologica; from Uruguay, Paraguay, Chile, and Argentine Republic.

Hutchinson, Dr. Edwin. Four small terra-cotta masks; from near San Juan de Teotihuacan, Mexico.

Illinois State Laboratory. Living turtle.

India, Kurrachee Municipal Library and Museum, James A. Murray, Curator. Collection of skins, heads and skulls of East Indian mammals.

Ingersoll, T. Dwight. Specimens of shells; from Lake Erie.

Irion, Dr. I. L. Spear-head and skull of alligator; from Texas.

Irwin, Alexander H. Sample of polished fossiliferous stone.

Jackson, Dr. E. E. Specimens of turtles, salamanders, and fishes; from South Carolina.

James, Dr. Frank L. Collection of pottery and stone implements; from Arkansas.

Jameson, John S. (See Washington, D. C., United States Fish Commission.)

Jefferson, Lieut. J. P., U. S. A. Specimen of *Aulostoma colorata*; from the Dry Tortugas, Florida.

Jellow, John H. (See Washington, D. C., United States Fish Commission.)

Jenison, O. A. Collection of stone axes, knives, fleshers, &c.; from Michigan.

Jenks, J. W. P. Lot of stone hammers found in old steatite quarry near Providence, R. I.

Jenner, David. Copper spear-head; from Wisconsin.

Jewett, Thomas. (See Washington, D. C., United States Fish Commission.)

Johnson, Capt. George A. (See Washington, D. C., United States Fish Commission.)

Johnson, Capt. Peter. (See Washington, D. C., United States Fish Commission.)

Johnson, Mr. (through J. E. Gere). Copper nodule; from Wisconsin.

Kaucher, William. Samples of fire-clay; from Wisconsin.

Kearney, William. (See Washington, D. C., United States Fish Commission.)

Keep, Josiah. Package of diatomaceous earth, from Massachusetts; alcoholic specimens of *Cerithidea sacrata*, from Lake Merritt, California.

Keithley, Mrs. E. (through Rev. F. B. Scheetz). Large stone celt; from Missouri.

Keller, John. Stone axe; from Missouri.

Kervey, H. F. Specimens of skins, nests, and eggs of birds, mammals, minerals, and Indian relics; from Maryland and Pennsylvania.

Kilpatrick, Capt. Briggs. (See Washington, D. C., United States Fish Commission.)

King, James. Three malformed eggs of domestic hen.

King, Larkin. Mineral; from Texas.

King, W. A. (See Washington, D. C., United States Fish Commission.)

King's Mountain Mine, North Carolina, Harney Beckwith, President. Machinery used in extracting gold at, and a series of the ores of, the King's Mountain Mine.

Kippen, John. (See Washington, D. C., United States Fish Commission.)

Klotz, H. E. Living iguana; from Navassa, W. I.

Knowles, Mr. Dried sound of hake.

Kocher, J. F. Three fœtal flying squirrels (*Pteromys volucella*); from Pennsylvania.

Kollmann, Dr. Collection of crania of the natives of Hungary, Austria, and Bavaria.

Kumlien, Ludwig. Skin, nest, and eggs of *Zonotrichia coronata;* from Shasta, California. Also 24 boxes of general natural history and ethnological collections; from Cumberland Island and Greenland.

Lake, C. W. Block of black-ash; from Michigan.

Lakeman, J. (See Washington, D. C., United States Fish Commission.)

Lamson, J. S., & Brother. Arrow-head and earth; from ancient grave in Chiriqui, Central America.

Langdon, Frank W. Collection of birds' skins and ethnological specimens; from Ohio.

Larkin, John. (See Washington, D. C., United States Fish Commission.)

Lauermann, Peter. Collection of flint arrow-heads, copper knife, two darts, and nodule; from Wisconsin.

Lawrence, J. J. Insect; from Beresford, Florida.

Lawson, James. Specimen of asbestos; from Alabama.

L'Acee, M. S. Specimen of calc-spar; from Texas.

Le Blanc, Simon. (See Washington, D. C., United States Fish Commission.)

Leonard, William. Specimen of ore; from Pennsylvania.

Leslie, C. C. Many fresh specimens of fish from Charleston, S. C., markets.

Lettermann, George W. Shell of periwinkle.

Lewis, James. Two boxes of living snails (*Vivipara contectoides*); from Mohawk, N. Y.

Lewis, W. H. Cast of canoe-shaped object, from Seneca Lake, New York; and box of minerals, from Westchester County, New York.

Lieber, H. Quartz pebble with adherent mica.

Lloyd, J. D. (See Washington, D. C., United States Fish Commission.)

Locke, W. M. Two boxes of stone implements; from Ohio and Western New York.

Lovett, Dr. A. A. Specimen of petrified coral; from Indiana.

Low, Maj. D. W., Postmaster, Gloucester, Mass. Collection of fossiliferour rocks; from George's Banks.

Lowe, Francis A. Specimens of copper and silver ores and amethyst; from the north shore of Lake Superior.

Lundberg, John A. (See Washington, D. C., United States Fish Commission.)

Lytte, A. E. Thirty-two specimens of cisco (*Argyrosomus*); from Geneva Lake, Wisconsin.

McBride, Sara J. Twelve samples of artificial trout-flies.

McClelland, Dr. M. A. Collection of stone implements; from Illinois.

McCollum, George. (See Washington, D. C., United States Fish Commission.)

McCook, Rev. J. J. Two human crania and box of Indian relics; from Niantic, Conn.

McCormick, E. G. Stone image (head); from Missouri.

McCown, General J. P. Box of ethnological and natural history specimens; from Arkansas.

McDonald, Duncan. (See Washington, D. C., United States Fish Commission.)

McDonald, James and John D. (See Washington, D. C., United States Fish Commission.)

McDonald, Capt. Jerome. (See Washington, D. C., United States Fish Commission.)

McDonald, Marshall. Specimen of Dufrènite; from Virginia.

McDonald, Capt. Matthew. (See Washington, D. C., United States Fish Commission.)

McDonald, Miles. (See Washington, D. C., United States Fish Commission.)

McDonald, Capt. William. (See Washington, D. C., United States Fish Commission.)

McEachern, Daniel. (See Washington, D. C., United States Fish Commission.)

McElderry, Dr. Henry, U. S. A. Package of marine diatoms; from Fort Monroe, Va.

McEntire, Daniel. (See Washington, D. C., United States Fish Commission.)

McGinnis, Captain. (See Washington, D. C., United States Fish Commission.)

McGuire, J. C. Lot of fragmentary steatite vessels; from Grimes Place, Md.

McGuire, J. D. Three polished-stone arrow-heads; from Howard County, Maryland.

McInnis, L. L. Chrysalis of moth; from Texas.

McKinley, William. Stone tube; from Georgia.

McKinnon, Capt. D. (See Washington, D. C., United States Fish Commission.)

McKinnon, Capt. John. (See Washington, D. C., United States Fish Commission.)

McNeill, J. A. (through J. S. Lamson & Co.). Nest and eggs of tinamoo; from Chiriqui, U. S. of Colombia.

McPhee, Capt. N. (See Washington, D. C., United States Fish Commission.)

McQuinn, Michael. (See Washington, D. C., United States Fish Commission.)

McQuinn, Edward. (See Washington, D. C., United States Fish Commission.)

Madden, Henry F. (See Washington, D. C., United States Fish Commission.)

Maggs, P. F. Moth; from Indiana.

Mansfield, James, & Sons. (See Washington, D. C., United States Fish Commission.)

Martin, Capt. George H. (See Washington, D. C., United States Fish Commission.)

Martin, S. J. (See Washington, D. C., United States Fish Commission.)

Marshall, Henry. Living snake (*Heterodon*); from Maryland.

Mason, Prof. O. T. Nest of meadow-lark (*Sturnella magna*).

Mason, Peter. (See Washington, D. C., United States Fish Commission.)

Mason, Hon. Roswell H., U. S. Surveyor-General, Montana. A large collection of minerals from various mines in Montana.

Masterson, Thomas. Glass and shell beads and fragments of Indian pipes; from Western Pennsylvania.

Mather, Fred. Two crustaceans.

Matteson, F. S. Bat (*Vespertilio pruinosus*); from Oregon.

Matthews, Dr. Edward, U. S. N. Jar of fishes, reptiles, and invertebrates; from Santo Domingo.

Mauler, Eugene. Samples of diatomaceous earths; from Italy, Jutland, and Bohemia.

Maw, Richard (through Anderson Merchant & Co., New York). Collection of tiles, pottery, and majolica, exhibited at the Permanent Exhibition, Philadelphia, Pa.

Meek, James. (See Washington, D. C., United States Fish Commission.)

Meigs, General M. C., U. S. A. Indian pipe of catlinite.

Menezer, Joseph. (See Washington, D. C., United States Fish Commission.)

Mercer, R. W. Collection of stone axes, arrow-heads, &c.; from Ohio.

Merchant, George J. (See Washington, D. C., United States Fish Commission.)

Merchant, Philip. (See Washington, D. C., United States Fish Commission.)

Merrill, Dr. J. C., U. S. A. Box of mammal and bird skins; from Texas.

Mexico, National Museum of, G. Mendoza, Director. A valuable collection of ancient Mexican pottery and stone relics.

Middleton, Carman & Co., New York. Two shad (*Alosa sapidissima*).

Middletown, Conn., Museum of Wesleyan College. A collection of fishes from Bermuda and one of reptiles from the New England States.

Miller, J. D. Rattlesnake (*Crotalus*); from New York.

Miller, Thomas I. Specimen of iron ore; from West Virginia.

Milner, J. W. Shells (*Viripara georgiana*), from Lake Monroe, Florida; salmon (*Salmo salar*), from Chesapeake Bay, Maryland; box of living salamanders (*Plethodon glutinosus*), from Albemarle Sound, North Carolina.

Mitchell, B. Specimens of ethnologica; from Illinois.

Mitchell, G. M. Specimen of "Quillback" (*Carpiodes* sp.); from Illinois.

Mitchell, Mr. (through Hon. George Williamson, United States Minister to Central America). Fœtal shovel-nosed shark from Acajutla, Salvador.

Möbius, Prof. Karl. Collection of mollusca; from Germany.

Mohr, C. Box of ethnological specimens; from Alabama.

Moody, H. A. Specimen of kaolin; from Mississippi.

Moore, Mr. H. C. (See Washington, D. C., United States Fish Commission.)

Moore. (See Porter, Dr. J. Y., U. S. A.)

Morris, A. P., Jr. Skull of possum (*Didelphys virginianus.*)

Morris, Edward S., & Co. Package of seeds of Liberian coffee plant.

Morrisey, Capt. Daniel C. (See Washington, D. C., United States Fish Commission.)

Morrisey, James D. (See Washington, D. C., United States Fish Commission.)

Morrison, Capt. R. N. (See Washington, D. C., United States Fish Commission.)

Morse, Prof. E. S. Collection of ethnologica, fishes and two rodents; from Japan.

Morsfelder, George. Copper spear-head; from Wisconsin.

Mortimer, Capt. J. H. Collection of dried marine animals; from the equatorial Pacific.

Motala Iron and Steel Manufacturing Company, Sweden. Collection of manufactured steel and iron, being their exhibit at the International Exhibition, 1876, at Philadelphia, Pa.

Munroe, Prof. Charles, E., U. S. N. Box of eocene tertiary fossils; from South River, Md.

Murphy, J. (See Washington, D. C., United States Fish Commission.)

Murphy, Michael J. (See Washington, D. C., United States Fish Commission.)

Murphy, Capt. Nicholas. (See Washington, D. C., United States Fish Commission.)

Murray, David. Living turtle; from Ellaville, Fla.

Mynster, William A. Two salmon; from Iowa.

Nelson, E. W., Signal Service, U. S. A. Nineteen boxes of general natural history and ethnological specimens; from Saint Michaels, Alaska.

Nevins, Rev. R. D. Upper jaw of *Hypsifario Kennerlyi*; from Oregon.

New Jersey, College of Princeton, N. J. Plaster casts of stone implements.

New Zealand, Auckland Museum, T. F. Cheeseman, Curator. Twenty-one crania of the Maori.

Newberry, Dr. J. S. Specimens of silicified wood; from California and Antigua, W. I.

Newlon, W. S. Specimens of *Productus punctatus*; from Kansas.

Newman, William P. Bone of turtle; from mound in Alabama.

Nesbit, John. Specimen of phosphatic rock; from Georgia.

Noble, Dr. H. B. Carved duck-shaped stone; from Northwest coast.

Nolan, Joseph. (See Washington, D. C., United States Fish Commission.)

Norris, J. E. Specimen of ore from the Gila mine, Nevada.

Norris, P. W., Superintendent of Yellowstone National Park. Collection of minerals, pottery, and stone implements.

Norton, Dr. (*through Rev. F. B. Scheetz*). Specimens of aboriginal stone implements; from Missouri.

Norway, W. H. Specimens of invertebrate fossils; from California.

Nott, W. R. (through Rev. F. B. Scheetz). Perforated tablet; from Missouri.

Nye, Willard, jr. Specimens of *Gasterosteus biaculeatus*; from New Bedford, Mass.

Ober, F. A. Seven boxes of general natural history and ethnological specimens; from various islands of the West Indies.

Olmsted, E. B. Box of stone implements; from Illinois.

Olsen, Captain. (See Washington, D. C., United States Fish Commission.)

Orme, William & Sons. Large living spider.

Osborne, L. C. Two oval hornstone disks; from Illinois.

Osgood, F. Storey. Two specimens of mineral; from Massachusetts.

Otis, Dr. George A. Two living iguanas; from Navassa, West Indies.

Palmer, Joseph. Mounted head of Virginia deer and specimen of snake (*Ophibolus doliatus*); from Virginia.

Palmer, William. Living snake (*Tropidonotus sipedon*); from Virginia.

Parsons, John. (See Washington, D. C., United States Fish Commission.)

Parsons, William. (See Washington, D. C., United States Fish Commission.)

Peacock, J. S. Jaw of shark (*Eulæmia Milberti.*)

Pearce, F. A. (See Washington, D. C., United States Fish Commission.)

Pease, A. P. L. Stone mortar; from Ohio.

Pease, W. B. Insect; from New Mexico.

Peel, J. R. Specimen of mineral; from Texas.

Pendleton, A. G., Deputy Surveyor, Arizona. Specimens of gold, silver, and copper ores; from Arizona.

Pensacola Ice Company, Florida. Many fresh specimens of fish taken in the vicinity of Pensacola, Fla.

Pergande, Theodore. Stone axe; from Missouri.

Peterson, Martin, and Dennis Theleueng. (See Washington, D. C., United States Fish Commission.)

Peterson, M. R. (See Washington, D. C., United States Fish Commission.)

Pettibone, William. Taylor-shad (*Dorysoma cepedianum*); from the Potomac River.

Pettingill & Cunningham. (See Washington, D. C., United States Fish Commission.)

Pfeil, John. Two fossils and two copper spear-heads; from Wisconsin.

Philadelphia, Zoological Society of, A. E. Brown, Superintendent. Specimen in flesh of Barbary Wild Sheep (*Ovis tragelaphus.*)

Phillips, D. A. Box of remains from Indian tumuli in Pennsylvania.

Phillips, J. P. Specimens of smelt; from Hancock County, Maine.

Pengry, John T. Tarpum (*Megalops thrissoides*); from Long Branch, N. J.

Poey, Prof. Felipe. Collection of turtles and fishes stuffed and dried; from Cuba.

Polsen, Alfred. (See Washington, D. C., United States Fish Commission.)

Porter, H. H. Specimens of artificially raised lake-, brook-, and salmon-trout.

Porter, Dr. J. Y., U. S. A., and Mr. Moore, Keeper of Loggerhead Light, Florida. Collection of fishes; from the Dry Tortugas, Florida.

Potter, Thomas. Specimens of clay from 60 fathoms deep in Long Island Sound.

Powel, Hon. Samuel. Collection of marine fishes; from Newport, R. I.

Preston, D. A. Box of lead and zinc ores; from Joplin, Mo.

Princeton, N. J., College of New Jersey. Casts of stone implements.

Pringle, O. M. Specimens of mineral; from Oregon.

Purman, D. Gray. Specimens of lead and zinc ores.

Putnam, Thomas J. Two "fool-fish" (*Pleuronectes glaber*); from Salem, Mass.

Queensland Acclimatization Society, Australia, Lewis A. Bernays, Vice-President. Sponge gemmules from river in Western Australia.

Quinlion, J. W. Teeth of fossil elephant, horse, and shark; from Bull River, South Carolina.

Radcliffe, William H. (See Washington, D. C., United States Fish Commission.)

Randle, Prof. E. H. Box of stone relics and minerals; from Kentucky.

Rau, Charles. Cast of ceremonial spear-head, from Saint Clair County, Illinois; and bat (*Vespertilio*), from Washington, D. C.

Reed, M. C. Specimen of shell conglomerate; from Ohio.

Reed, Thomas. Living iguana; from Navassa, West Indies.

Reid, A. J. Specimens of fish (*Notemigonus chrysoleucus*); from the Fox River, Wisconsin.

Reynolds, A. M. Specimens of minerals.

Reynolds, Elmer R. Two boxes of fossils, fragmentary pottery, and arrow-heads; from Virginia.

Reynolds, J. H. Collection of stone relics and pottery; from West Virginia.

Rhodes, B. V. Large bug; from Indiana.

Rich, Capt. A. F., Boston, Mass. (See Washington, D. C., United States Fish Commission.)

Richmond, A. G. Cast of Indian stone ornament.

Ridgway, Robert. Four boxes of general natural-history specimens; principally from Illinois.

Riley, William. (See Washington, D. C., United States Fish Commission.)

Roach, David. (See Washington, D. C., United States Fish Commission.)

Robbins, Elisha. String of cells of periwinkle.

Roberts, N. E. Four living turtles (*Cistudo*); from Fairfax County, Illinois.

Roessler, A. R. Specimens of jasper; from North Carolina.

Rogers, ———. Samples of various kinds of fish-glue.

Romig, Rev. B. Two boxes of shells, fossils, and woods; from Antigua, West Indies.

Ronex, W. J. Tail of milk-snake (*Coluber eximius*).

Roop, C. Five small arrow-heads; from Oregon.

Ross, A. C. Three boxes of Indian stone relics; from Ohio.

Rosser, B. R. (*through Rev. F. B. Scheetz*). Part of flint ceremonial implement; from Missouri.

Rowe, George T. (See Washington, D. C., United States Fish Commission.)

Rowe, Capt. John. (See Washington, D. C., United States Fish Commission.)

Rowe, Timothy S. (See Washington, D. C., United States Fish Commission.)

Rust, Miss Carrie A. (See Washington, D. C., United States Fish Commission.)

Rust, H. N. Cast of Franklin on Ring cent of the United States, 1787.

Rust, John R. Double-headed lamb.

Russia. Herbarium of Botanic Gardens, St. Petersburg, C. J. Maximowicz, Director. Over two hundred species of Japanese plants.

Ruth, Dr. M. L., U. S. N. Collection of alcoholic reptiles and fishes; from the Madeira River, Brazil.

Sale, C. J. Beetle; from Virginia.

Sammis, Col. J. S. Specimen of living snake (*Abastor erythrogrammus*); from Florida.

Sandvik Iron and Steel Works, Sweden. Collection of manufactured iron and steel, being their exhibit at the International Exhibition, 1876, at Philadelphia.

Sanford, H. G. Fossiliferous boulder; from George's Banks.

Sargent, Senator A. A. Box of fossils; from California.

Saunders, Howard. Five skins of gulls and terns; from Europe.

Savage, Joseph. Box of invertebrate fossils; from Kansas.

Sayler, Marcus. Collection of Indian stone implements; from Ohio and Illinois.

Sayward, E. P., jr. (See Washington, D. C., United States Fish Commission.)

Schanno, Joseph. Sample of fir-sugar; from Washington Territory.

Schneck, Dr. J. A large collection of living turtles and terrapins, and a box of water-plants; from Illinois.

Scott, George W. (See Washington, D. C., United States Fish Commission.)

Scupham, J. R. Small reptile; from Kern County, California.

Sells, P. R. Box of stone implements and pottery; from Georgia.

Sennett, George B. A collection of bird-skins; from Fort Brown, Texas.

Serviss, E. F. Box of ethnological specimens; from Kansas.

Shelby, D. Parasphenoid bone of alligator-gar.

Shemelin, Joseph P. (See Washington, D. C., United States Fish Commission.)

Shemelin, James C. (See Washington, D. C., United States Fish Commission.)

Shindler, A. Z., and *George H. Boehmer.* Large stone axe; from Virginia.

Sibley, H. F. Specimens of stone implements; from Illinois.

Silva-Terra, Anton. (See Washington, D. C., United States Fish Commission.)

Simons, Capt. A. (See Washington, D. C., United States Fish Commission.)

Singleton, John. Copper chisel; from Illinois.

Small, George. Specimens of alewives; from Bucksport, Me.

Small, E. E. Specimen of "spinous shark" (*Echinorhinus spinosus*); from Provincetown, Mass.

Smith & Oakes. (See Washington, D. C., United States Fish Commission.)

Smith, Douglas B. Specimens of shells and beads; from Evanston, Ill.

Smith, Jacob. Skin of Wilson's phalarope (*Phalaropus wilsonii*); from Manitoba.

Smith, James A. Series of manufactured clay tobacco-pipes.

Smith, Prof. H. L. Four alewives (*Pomolobus vernalis*); from Geneva, N. Y.

Smith, John L. (See Washington, D. C., United States Fish Commission.)

Smith and Oakes. Specimen of yellow cod (*Gadus morrhua*); from Gloucester, Mass.

Snyder, T. W. Five invertebrate fossils; from Illinois.

Sorensen, John P. Specimen of ore; from Utah.

Southwick, J. M. K. Two samples of codfish-hooks.

Soutter, August. Case of mounted birds and photographs.

Spalding, R. M. (through *Rev. F. B. Scheetz*). Two stone axes; from Missouri.

Sperry, Mrs. James L. Eight skins of California birds.

Spurr, Captain. (See Washington, D. C., United States Fish Commission.)

Stabler, J. P. Specimens of living snakes; from Maryland.

Stanske, Charles. Copper nodule and stone axe; from Wisconsin.

Staples, Edwin B. Two boxes Indian relics, one box turtles (*Pseudemys mobiliensis*), and shell mouth-peg; from Florida.

Stearns, Silas. Ten boxes of specimens of fish and shell, including type of new fish, *Caulolatilus microps* Goode & Bean; from Florida.

Steele, W. N. Living snake (*Ophibolus doliatus doliatus*); from Maryland.

Stevens, James A. Collection of shells; from Summit County, Ohio.

Stewart, W. E. Five shad (*Alosa sapidissima*); specimen of *Elops saurus*; from the Potomac River.

Stone, Livingston. Large collection of alcoholic fishes, from the McCloud River, California; also, one box fossils, from California.

Story, L. D. (See Washington, D. C., United States Fish Commission.)

Stout, W. C. Branchial apparatus of *Lepidosteus.*

Studley, Edwin. Grooved stone axe; from Wisconsin.

Sumner, M. T., jr. Sections of oak showing old surveyor's marks.

Sutherland, John. Specimen of land-locked salmon (*Salmo salar*, var. *sebago*); from the Merrimac River.

Swan, James G. Collection of fishes, in alcohol; and specimens of bone implements used by the Haidah Indians; from Washington Territory.

Sweden. Academy of Sciences, Stockholm. Ten species of shells; from Nova Zembla.

Sweeney, Frank. (See Washington, D. C., United States Fish Commission.)

Sweet, Capt. William E. (See Washington, D. C., United States Fish Commission.)

Symmes, Rev. Francis M. Box of ethnological specimens; from Orange County, Indiana.

Tarr, Capt. James. (See Washington, D. C., United States Fish Commission.)

Tarr, James G. (See Washington, D. C., United States Fish Commission.)

Tatham & Co., New York. Bag of "dust" shot.

Taylor, Rev. Horace J. Collection of shells, beetles, and ethnological specimens; from the Gilbert and Marshall Islands.

Thompson, Capt. William. (See Washington, D. C., United States Fish Commission.)

Thompson, W. H. Mass of quartz crystals; from Tye River, Virginia.

Thomson, J. H. Crab taken from hold of the bark Osprey, New Bedford, Mass.

Thorpe, Rev. Thomas M. Wing and bill of woodpecker and four hickory-nuts; from Arkansas.

Tobey, Gerard C. *Squilla*; from Buzzard's Bay, Rhode Island.

Toellner, A. Fragments of human skull and pottery; from mound in Illinois.

Towers, David. Living slug; from Washington, D. C.

Towner, Wayne. Gypsum; from Pennsylvania.

Tresilian, Thomas. (See Washington, D. C., United States Fish Commission.)

Triece, W. G. Specimens of snake and turtle; from Pennsylvania.

Turner, C. W. S. Four arrow-heads; from Virginia.

Turner, L. M. Turtle (*Malacoclemmys peudo-geographicus*); from Southern Illinois.

Turner, Mrs. M. E. Three boxes of living turtles; from Southern Illinois.

Turkey. Robert College, Constantinople. Collection of bird-skins.

Van Dyck, W. T. Three boxes of general natural-history collections; from Syria.

Van Hook, J. C. Snake (*Coluber obsoletus obsoletus*); from Virginia.

Vance, James A. Mineral; from Arkansas.

Velie, Dr. J. W. Collection birds' eggs and shells, from Florida; cast of stone axe, two living turtles and living snake, from Illinois.

Voss, A. (See Washington, D. C., United States Fish Commission.)

Wade, Joseph M. Pectoral of flying-fish, taken in the South Pacific Ocean.

Walker, Dr. R. L. Four living hell-benders (*Menopoma alleghaniensis*); from Western Pennsylvania.

Wallace, James B. Insect; from Texas.

Wallace, John. Two Australian parrakeets.

Wallis, Dr. G. B. Specimens of fossils and copper ore.

Walton, W. B. Oyster with double shell.

Washington, D. C.:

Department of State, U. S. A. (See under name of *Hon. G. A. Williamson*, United States minister to Guatemala.)

Treasury Department, U. S. A.:

United States Revenue-Marine. (See under name of *Capt. Alfred B. Davis.*)

United States Coast Survey. (See under name of *W. H. Dall.*)

War Department, U. S. A.:

United States Army. (See under names of *General M. C. Meigs, Col. A. G. Brackett, Lieut. George M. Wheeler*, and *Lieut. J. P. Jefferson.*)

Surgeon-General's Office, United States Army Medical Museum (Dr. G. A. Otis, in charge.) A collection of bird and mammal skins, fossils, ethnologica, &c., collected in Texas by *Dr. R. H. White*, U. S. A. (See also under the names of *Drs. J. Y. Porter, W. Whitney, T. E. Wilcox*, and *H. C. Yarrow*, medical officers United States Army.)

Surveys west of the one hundredth meridian, Lieut G. M. Wheeler in charge. Collection of mortars and pestles, pottery, arrows, quivers, &c., also a large collection of plants; from Arizona and California.

Bureau of Ordnance, General S. V. Benét. Specimens of copper-ore from Rock Island, Ill.

Signal Service, United States Army. (See under name *Private E. W. Nelson.*)

Washington, D. C.—Continued.

Navy Department, U. S. A.:

Bureau of Navigation, Commodore Whiting in charge; 63 bottles of soundings made by the United States steamer Tuscarora.

Surgeon-General's Office. (See under names of *Drs. M. L. Ruth* and *Robert Whiting, medical officers United States Navy.*)

Agricultural Department, U. S. A., Hon. W. G. Le Duc, Commissioner: Two pairs of antlers of Virginia deer; sucker-fish (*Catostomus*) from Alabama.

Interior Department, U. S. A.:

General Land Office. (See under the names of *Surveyors-General Roswell, H. Mason* and *John Wasson*; also under name of *P. W. Norris, superintendent Yellowstone National Park.*)

United States Commission of Fish and Fisheries. (*Prof. Spencer F. Baird, Commissioner.*) About 100 boxes zoological collections from Gloucester, Mass., and vicinity, made by *Prof. A. E. Verrill, G. Brown Goode,* and *Tarleton H. Bean.* (See also under names of *Charles G. Atkins, Tarleton H. Bean, H. C. Chester, F. N. Clark, Vinal N. Edwards, G. Brown Goode, James W. Milner,* and *Livingston Stone.*) Specimens have also been obtained by the commission from the following parties:

Anderson, Capt. Charles, and crew of schooner Alice G. Wonson. A collection of fishes, corals, shells, sponges, &c.; from George's Bank.

Atkinson, John. Skull of codfish (*Gadus morrhua*); malformed claw of lobster (*Homarus americanus*).

Allen, George K., schooner Marion. Specimen of gold-banded rush-coral (*Keratoisis ornata*).

Allen, George K., schooner M. H. Perkins. Collection of corals, sponges, sea-feathers, and fishes; 40 miles southwest of Sable Island.

Anderson, Capt. Chris, schooner Solomon Poole. A large and interesting collection of living hydroids, bryozoans, sponges, &c.; from 15 miles off Pollock Rip Light-Ship.

Andrews, F. S. Specimen of spider-crab brought in by schooner Clara B. Sweet from Middle Bank.

Babson, Fitz J. Specimen of "old wife" (*Harelda glacialis*) shot in Squam River, and axis of coral.

Babson, Fitz J., jr. Lobster (*Homarus americanus*), with deformed claw.

Babson, William H., schooner Marion. Axis of coral (*Primnoa reseda*), from Banquereau.

Baker, Captain, schooner Peter D. Smith. Specimen of young dog-fish (*Squalus americanus*), lump-fish (*Cyclopterus lumpus*), &c.

Bansett, William A., New Bedford, Mass. Pilot-fish (*Naucrates ductor.*)

Bartlett, A., New Bedford, Mass. Rabbit-fish (*Tetrodon lævigatus*); from Buzzard's Bay.

Bates, James. Rough swell-fish (*Chilichthys turgidus*).

Blackburn, Capt. William, schooner Charles Carroll. Part of skull of whale covered with bryozoans and sponges; from western part of George's Bank.

Blatchford, Capt. B. F. Specimen of bush-coral (*Primnoa reseda*); from Banquereau.

Washington, D. C.—Continued.

U. S. Commission of Fish and Fisheries—Continued.

Brazier, Benjamin S. String of eggs of *Sycotyphus canaliculatus*, from Monomy Beach; and pebbles from Steelwagen's Bank, covered with bryozoa.

Briggs, Captain, schooner City of Gloucester. Samples of fish-oil made on the Grand Bank.

Brown, William, schooner Marion. Three specimens of black dog-fish new to the coast.

Burbank, Martin. Young lobster (*Homarus americanus*); from Monhegan Island.

Burke, Henry E., schooner Hattie S. Clark. Bryozoans and sea-corn; from the Grand Bank.

Burns, Thomas. Specimens of gull (*Larus delawarensis*) and star-fish (*Hippasteria*), from off Gloucester; specimens of chimæra and lancet-mouth (*Alepidosaurus ferox*); from George's Bank.

Butler, Isaac, schooner Esther Ward. Specimens of star-fish, sponges, &c.; from Brown's Bank.

Calderwood, Capt. M. W., schooner Jennie M. Calderwood. Perforated rocks with sponges and shells attached; from Western Bank, 68 fathoms.

Capron, John, schooner Solomon Poole. A large and beautiful collection of branching bryozoan corals; from the Grand Banks.

Carlsen, Arnold, schooner Alice G. Wonson. Specimen of rush-coral (*Acanella*); from between Brown's and George's Bank.

Carritt, William, schooner Mary E. Shell new to America; from Flemish Cap.

Carroll, Capt. Daniel. Skua gull (*Stercorarius skua*); from George's Bank.

Cavener, Nicholas, schooner Marathon. *Chalina* sponge and dog-fish skins; from George's Bank.

Childs, Edward R., schooner Mary F. Chisholm. Young green turtle (*Chelonia mydas*); from SE. Le Have.

Clark, Benjamin, schooner Water Sprite. Vase-shaped sponge (*Phakellia*); from Brown's Bank.

Clinton, Capt. George T., schooner Henry Wilson. Barnacles, bryozoans, sea-corn, &c.; from Grand Bank.

Colby, Capt. Charles. Pipe-fish (*Syngnathus* sp.) and star-fish (*Hippasteria phrygina*); taken eight miles off Gloucester.

Collins, Capt. Joseph W., schooner Marion. A large and very valuable collection of fishes, sponges, shells, and other marine animals, many of which are new both to the American fauna and to science.

Collins, William. Jaws of shark caught off Monhegan Island.

Conley, John. Specimens of finger-sponge (*Chalina*) and mackerel-shark (*Lamna cornubica*); from off Gloucester.

Cressy, Charles C. Specimens of oceanic dolphin (*Coryphæna punctulata*); from the Grand Bank.

Cunningham & Thompson. Very large sponge; from Le Have Bank.

Curtis, Capt. Andrew, ship Ida Lily of Richmond. Pens of squid (*Sepia*), from Cadiz Bay; larval lobster (?); fossiliferous rock; from George's Bank.

Danforth, John. A large sea-worm.

Davis, Mrs. Abby L. Fossiliferous rock; from George's Bank.

Davis, Mrs. Mary E. Fossiliferous bowlder; from Banquereau.

Demsey, Capt. William, schooner Everett Steele. Parasites of codfish (*Æga psora*); from George's Bank.

Devan, James, schooner Flying Scud. Base of coral; from Eastern George's.

Devoe, Capt. Luke, schooner Epes Tarr. Branching bryozoans and sea-corn; from Grand Bank.

Washington, D. C.—Continued.

U. S. Commission of Fish and Fisheries—Continued.

Dixon, Eugene F., schooner William T. Smith. Hydroids and bryozoa; from 15 miles off Virgin Rock.

Dixon, Capt. George W., schooner William T. Smith. Bryozoans and sea-corn; from George's Bank.

Douglass, Capt. George, schooner Constitution. Specimens of lump-fish, dollar-fish, rock-eel, moon-fish, &c., and a crustacean (*Idotea robusta*); from Casco Bay.

Douglass, John, specimen of ribbon-snake (*Eutænia saurita*).

Douglass, Robert, 2d. Specimen of phantom-eel (*Leptocephalus*); from off Gloucester.

Driscoll, Daniel, schooner Solar Wave. Bush coral; from Banquereau.

Dulaney, John. Rare holothurian; from off Gloucester.

Duncan, Capt. J. F., schooner Mary Low. A very large sponge; from Sable Island Bank.

Floyd, Joseph D. Fossiliferous boulder and rock perforated by *Saxicava arctica*; from George's Bank.

Friend, Sidney. Same as above.

Gaffney, William M. Rock covered with barnacles and bryozoans and fossiliferous boulder; from George's Bank.

Getchell, Capt. John Q., schooner Otis P. Lord. Specimens of fish, sponges, corals, &c., two living hagdons, shells; from George's and Brown's Banks, and Cape Cod.

Ginnevan, Thomas, and Philip Merchant. Two very large spider-crabs (*Lithodes maia*).

Goodwin, Capt. Thomas, schooner Elisha Crowell. Coral (*Acanthagorgia*), from Western Bank; eyes of fishes, coral, and sponge, from Sable Island Bank; lancet-mouth (*Alepidosaurus ferox*), from Le Have Bank.

Goodwin, Thomas, schooner Bellerophon. Limestone rock containing fossil shells (*Cyprina*); from Grand Bank.

Gorton, Slade, & Co. Specimens of "red" salted swordfish and codfish.

Goslin, Capt. Joseph, schooner Shooting Star. Chalina sponge; 25 miles southeast of Sankaty Head.

Gourville, Capt. John, schooner Rebecca Bartlett. Specimens of fish (*Anarrhichas lupus, Triglops, Sebastes*), shells, star-fish (*Crossaster papposus*), sponges (*Chalina, Isodictya*), crabs, bryozoa, &c., &c.; from George's Bank.

Greenleaf, Capt. William H., schooner Chester R. Lawrence. Specimens of fish (*Haloporphyrus viola, Synaphobranchus pinnatus, Petromyzon*, &c.), great northern sea-feather (*Pennatula borealis*), corals (*Flabellum, Acanthomastus, Acanthagorgia*); from George's Bank.

Hamlen, Capt. Peter, schooner Andrew Leighton. Wolf-fish (*Alepidosaurus ferox*) and pug-nosed eel; from George's Banks.

Harvey, Edward, schooner Rebecca Bartlett. Small crustacean (*Idotea robusta*); from George's Bank.

Haskell, Samuel. Fossiliferous boulder brought by schooner Conductor, Captain Curtis; also, bryozoans and fossiliferous boulder from Grand Bank, brought in by schooner Etta E. Turner, Captain Olsen.

Hawkins, Capt. James, schooner Gwendolen. Basket star-fish, black rudder-fish (*Palinurichthys*), slime-eel (*Myxine*), crabs, shells, &c.; from Saint Peter's and Le Have Banks.

Hawkins, Capt. Z., schooner Gwendolen. Fishes (*Zoarces, Petromyzon, Synaphobranchus*, &c.), embryo sharks, star-fishes, crabs; from George's Bank.

Herring, Richard, schooner William H. Raymond. Large gray gannet (?) and fossiliferous rocks; from NE. George's Bank.

Washington, D. C.—Continued.

U. S. Commission of Fish and Fisheries—Continued.

Hewitt, Isaac S., schooner J. J. Clark. Large bunch of barnacles (*Balanus porcatus*); from Middle Bank.

Higgins & Gifford. *Model of a Gloucester fish-wharf and houses.*

Hillier, Fred., schooner Alice M. Williams. Two rare species of eel-like fishes and bush-coral (*Acanella normani*) with basket-fish attached.

Hodgdon, Capt. T. F., schooner Bessie W. Somes. Collection of corals (*Acanella normani*), sponges, sea-feathers (*Pennatula borealis, P. aculeata, Balticina, Finmarchicha*), shells, &c.; from Sable Island Bank.

Hodgkins, Edward W. Crabs (*Leithodes maia* and *Cancer irroratus*); from Gloucester.

Homans, Capt. Charles A. Specimens of Sipo wood used by the Carib Indians, of South America, for intoxicating and catching fish. Specimens of codfish from the West Indian market.

Hoy, George W., schooner Mary F. Chisholm. File-fish (*Balistes capriscus*) and axis of sea-pen; from Le Have Bank.

Hurlbert, Capt. R. H. Eggs of periwinkle, from Cape Henlopen; Gunther's midge (*Hypsiptera argentea*), from off Cape May; shells of scallop and herring-spawn from George's Bank.

Jameson, John S., schooner Henry Wilson. Bryozoans, scallops, and sea-corn; from Grand Bank.

Jellow, John, schooner Laura Nelson. Fragments of gold-banded rush-coral (*Keratoisis ornata*); from Le Have Bank.

Jellow, John H., schooner George P. Whitman. Specimens of coral (*Acanella normani, Primnoa reseda*), snails (*Lunatia*), and scallops (*Pecten*); from Le Have and George's Banks.

Jewett, Capt. Thomas, schooner City of Gloucester. Specimens of sponge, fan-shaped and gold-banded corals, sea-pens (*Pennatula*), &c.; from Le Have Bank.

Johnson, Capt. George A., schooner Augusta Johnson. A large and interesting lot of rare fishes, including the grenadier (*Macrurus Fabricii*), chimæra (*Chimæra plumbea*), black dog-fish (*Centroscyllium* and *Centroscymnus*), wolf-fish (*Anarrhichas lupus*), (*Synaphobranchus*), shells, sponges &c.; from Sable Island and George's Banks.

Johnson, Capt. Peter. Collection of shells, star-fishes, sea-cucumbers, &c.; from George's Bank.

Kearney, William, schooner Marathon. Chalina sponge; from George's Bank.

Kilpatrick, Capt. Briggs, schooner City of Gloucester. A rare sucker-fish (*Remoropsis brachyptera*) taken from the gills of a swordfish.

King, W. A., schooner Otis D. Dana. Bush-coral (*Primnoa reseda*); from George's Bank.

Kippin, John, schooner Solomon Poole. Chalina sponge, and stones bored by *Saxicava arctica*; from Grand Bank.

Lakeman, J. Spider-crab (*Leithodes maia*).

Larkin, John, schooner George W. Stetson. Young hagdon, living.

Le Blanc, Simon, schooner Rebecca Bartlett. Star-fish (*Crossaster papposus*); from George's Bank.

Lloyd, J. D. Stones bored by *Saxicava arctica*, fossils, &c.; from George's Bank.

Lundberg, John A. Sponge (*Chalina aculeata*); from George's Bank.

McCallum, George, schooner Fitz J. Babson. Specimen of the King-of-the-herring (*Chimæra plumbea*); from Le Have Bank.

McDonald, Duncan, schooner Polar Wave. Specimens of coral and "turbot" (*Platysomatichthys hippoglossoides*); from Eastern Banquereau.

Washington, D. C.—Continued.

U. S. Commission of Fish and Fisheries—Continued.

McDonald, James and John D., schooner Addison Center. Old-fashioned iron kettle; hauled up on trawl near Halifax, N. S.

McDonald, Capt. Jerome, schooner G. P. Whitman. Rare barnacles and King-of-the-herring (*Chimæra plumbea*); from Le Have Bank; two specimens of lancet-mouth (*Alepidosaurus ferox*); from George's Bank.

McDonald, Capt. Matthew, schooner Lizzie K. Clark. Specimens of rare fish (*Chimæra plumbea, Synaphobranchus pinnatus*), corals (*Keratoisis, Acanthagorgia, Acanella*), shells, sponges, sea-feathers, &c.; from Western and Sable Island Banks.

McDonald, Miles. Sea-mouse (*Aphrodite aculeata*); from Middle Bank.

McDonald, Capt. William, schooner N. H. Phillips. Five specimens of coral (*Acanella normani*); from SE. Le Have Bank, and one (*Paragorgia*) from Seal Island Bank.

McEachern, Daniel, schooner Guy Cunningham. Bases of fan-shaped coral taken on Grand Bank; and specimens of eels (*Myxine and Petromyzon*); sponges and sea-anemones; from George's Bank.

McEntire, Daniel. Gypsum; from mouth of Saint Lawrence River.

McGinnis, Captain, schooner M. H. Perkins. Black dog-fish (*Centroscymnus cœlolepis*); from Sable Island Bank.

McKinnon, Capt. Daniel., schooner Mary F. Chisholm. Specimens of fish (*Myxine, Sebastes Petromyzon*), crabs, corals, &c.; from Sable Island and Le Have Banks.

McKinnon, Capt. John, schooner R. B. Hayes. Spider-crab (*Leithodes maia*); from 25 miles off Gloucester, SE.

McPhee, Capt. N., and crew, of schooner Carl Schurz. Specimens of corals (*Alcyonium, Flabellum, Acanella*), sea-feathers, star-fish, parasites of halibut (*Æga psora*), &c.; from near Sable Island Bank.

McQuinn, Edw. Specimens of *Remoropsis brachyptera;* brought in by schooner W. H. Perkins from Grand Bank.

McQuinn, Michael, schooner N. H. Phillips. Rare shells (*Aporrhais*), and eggs of shark; from George's Bank.

Madden, Henry F. Axis of tree-coral (*Primnoa reseda*); from off Sable Island.

Mansfield, James, & Sons. Fossiliferous boulder; from George's Bank.

Marble, Frank. Large finger-sponge (*Chalina*), King-fish (*Menticirrus nebulosus*), and fish-spawn; from Norman's Woe.

Martin, Capt. George H., schooner Northern Eagle. Specimens of fish, crustacea, barnacles, hydroids, &c., from between Boone Island and Matinicus Rock, swordfish (*Xiphias gladius*); taken off Portland, Me. (purchased); 5 swords of swordfish from South Channel; pipe-fish (*Syngnathus fuscus*); from Provincetown, Mass.

Martin, Capt. S. J. Living specimen of hagdon (*Puffinus anglorum*); from George's Bank.

Mason, Peter. Shells and hydroids taken by crew of schooner Hattie S. Clark on Grand Bank.

Meek, James, schooner Alice G. Wonson. Specimen of tree-coral (*Paragorgia arbuscula*); from between Brown's and George's Banks.

Menezer, Joseph. Herring-gull; from Gloucester, Mass.

Merchant, George, jr., schooner Hattie B. West. A small goose-fish (*Lophius piscatorius*) taken off Cape Elizabeth.

Merchant, Philip, schooner Marion. Specimens of coral (*Mopsia, Keratoisis,* and *Acanella*); from 30 miles off Sable Island.

Washington, D. C.—Continued.

U. S. Commission of Fish and Fisheries—Continued.

Moore, H. C., schooner Chester R. Lawrence. Tusk of walrus; found on the east coast of Newfoundland.

Morrissey, Capt. Daniel C., schooner Alice M. Williams. Two specimens of bush-coral (*Acanella normani*); from the Western Bank.

Morrissey, Capt. James D., schooner Alice M. Williams. Specimens of fish (*Chimæra plumbea, Centroscymnus cœlolepis, Petromyzon*) and coral; from George's Bank.

Morrison, Capt. R. N., schooner Laura Nelson. Lamper-eel (*Petromyzon*) and fragments of tree-coral (*Paragorgia arborea*); from Le Have Bank.

Murphy, J., schooner Gertie Foster. A beautiful sponge; from George's Bank.

Murphy, Michael J., schooner Magic. Specimen of tree-coral (*Paragorgia arborea*); from Grand Bank, and bush-coral (*Acanella normani*); from Banquereau.

Murphy, Capt. Nicholas, schooner Franklin S. Schenck. Pebbles covered with bryozoans; from Whaleman's Shoal off Nantucket.

Nolan, Joseph, schooner Bessie W. Somes. Specimen of bush-coral (*Primnoa reseda*); from Banquereau.

Olsen, Capt. Chris., and crew, schooner William Thompson. Specimens of sea-mouse (*Aphrodite*) star-fish, hydroids, bryozoans, &c.; from Grand and Le Have Banks.

Parsons, John. Young pipe-fish (*Syngnathus fuscus*).

Parsons, William. Specimen of snipe-eel (*Nemichthys scolopaceus*); taken by schooner Howard Steele, on George's Bank in 1875.

Pearce, F. A. Specimens of fish, star-fish, shells, &c.; from Western Bank.

Peterson, Martin, and *Dennis Theleueng, schooner William Thompson.* Specimens of rare fish (*Alepidosaurus ferox, Macrurus Fabricii, Centroscymnus cœlolepis*) and coral; 39 miles off Sable Island.

Peterson, M. R., schooner Guy Cunningham. Specimen of gold-banded rush-coral (*Keratoisis ornata*) with barnacles attached, &c.

Pettingell & Cunningham. Fossiliferous boulders bored by *Saxicava;* from George's Bank.

Polsen, Alfred, schooner Mary E. Hat-sponge from Flemish Cap.

Radcliffe, William H., yacht Uncle Sam. Sea-lemon (*Boltenia*); from off Gloucester, Mass.

Rich, Capt. A. F., Boston, Mass. Specimen of sucker-fish (*Remoropsis brachyptera*); from South Channel.

Riley, William, schooner Grace C. Hadley. Living fulmar-petrel; from George's Bank.

Roach, David, schooner Lizzie K. Clark. Tobacco-pipe made from axis of tree-coral.

Schooner Alice G. Wonson. Lancet-mouth (*Alepidosaurus ferox*), corals (*Paragorgia arborea, Flabellum articum, Primnoa reseda*), star-fishes, shells, &c.; from between George's and Le Have Banks.

Schooner Carl Schurz. King-of-the-herring (*Chimæra plumbea*) and bush-coral (*Acanella normani*); taken 30 miles south of Sable Island; also sword of swordfish.

Schooner Charger. Specimen of spider-crab (*Leithodes maia*); from Marblehead Bank.

Schooner G. P. Whitman. Rock covered with bryozoans; from Banquereau.

Schooner Grace C. Hadley. Stone covered with barnacles and bryozoa; from George's Bank.

Schooner Howard Holbrook. Scallop-shells; from Grand Bank.

Washington, D. C.—Continued.

U. S. Commission of Fish and Fisheries—Continued.

Schooner Josie M. Calderwood. Perforated rocks with sponges and shells adhering; from George's Bank.

Schooner Lizzie K. Clark. Shells of *Buccinum cyaneum;* from 30 miles south of Sable Island.

Schooner Northern Star. Three living hagdons (*Puffinus anglorum*); from Grand Bank.

Schooner Otis P. Lord. Collection of star-fishes (*Crossaster papposus*), barnacles, sea anemones, &c.

Schooner Phœnix. Skin of spear-fish (*Tetrapturus albidus*); taken in the South Channel.

Schooner Rebecca Bartlett. Tail of swordfish (*Xiphias gladius.*)

Schooner Wachusett. Collection of scallops, hydroids and barnacles; from Grand Bank.

Rowe, George T. Specimen of *Zoarces;* from off Gloucester.

Rowe, Capt. John. Specimen of bush-coral (*Primnoa reseda*); from Banquereau.

Rowe, Timothy S. Specimen of "gulf-weed;" from the Gulf Stream.

Rust, Miss Carrie A. Barnacles (*Lepas fascicularis*); from Harpswell, Me.

Sayward, E. P., jr. Fossiliferous rocks; from George's Bank.

Scott, George W., schooner Lizzie. Collection of rare fishes (*Centroscyllum Fabricii, Centroscymnus cœlolepis, Chimæra plumbea*), shells, sponges, corals, &c.; from Banquereau.

Scott, George W., schooner Edwin C. Dolliver. Specimens of fish (*Haloporphyrus, Anarrhichas, Phycis, Synaphobranchus, Chimæra*), devil fish (*Octopus Bairdii*), corals (*Alcyonium, Keratoisis*), sea-feathers (*Pennatula, Balticina*), shells, &c.; from lat. 43° 23′, long. 60° 16′.

Scott, George W., schooner City of Gloucester. Sample of black-dog-fish oil.

Shemelia, Joseph P., schooner William H. Raymond. A large collection of living water-birds, five species; from NE. George's Bank.

Shemelia, James C., schooner William H. Raymond. Chalina sponge, barnacles, hydroids, and bryozoans; from George's Bank.

Silva-Terra, Anton, schooner Rebecca Bartlett. Specimens of dog-fish skin.

Simons, Capt. A., schooner Defiance. Living specimen of sea-robin (*Prionotus*); from the Brewsters.

Smith, John L. Specimens of sea-corn taken by schooner Conductor on Grand Bank; also tree-coral from George's Bank.

Smith & Oakes. Fossiliferous boulder bored by *Saxicava;* from George's Bank.

Spurr, Captain, schooner John F. Wonson. Muscles, hydroids, bryozoans, &c.; from George's Bank.

Story, L. D., Magnolia. Small fish (*Argyreiosus vomer*); from Magnolia.

Sweeney, Frank. Parasites from gills of codfish taken off Gloueester.

Sweet, Capt. William E., schooner Grace C. Hadley. Sea-cucumber (*Thyonidium Dubenii*), star-fish, and parasites of cod (*Æga psora*); from George's Bank.

Tarr, Capt. James. French hooks taken from the stomach of codfish on shoal ground off Salvages in 1856 and Jeffries Ledge, 1876.

Tarr, James G. Samples of fish-oil.

Thompson, Capt. William, schooner Magic. Collection of corals, sponges, sea-feathers, shells, &c.; from Sable Island Bank and Banquereau.

Tresilian, Thomas. Tree-coral (*Primnoa reseda*); from George's Bank.

Voss, A. "Devil's claw," or box-hook used in boxing halibut.

Washington, D. C.—Continued.

U. S. Commission of Fish and Fisheries—Continued.

Webb, Capt. Henry, Rockport. Specimens of pollock, whiting, and Greenland sculpin; from Milk Island, Rockport. Also, lobster-pot bait-hook.

Wells, Capt. William N., schooner E. B. Phillips. Shells from Grand Bank.

Welsh, Capt. James, schooner Martha and Susan. Specimen of chalina sponge; from George's Bank.

Welsh, Morris. Specimen of chalina sponge; from George's Bank.

Whiting, Henry, schooner Webster Sanborn. A large collection of shells (*Pecten islandica, Rhynchonella*, sp.); from Grand Bank.

Whitman, George P., Rockport. Mounted specimens of Richardson's jæger-gull (*Stercorarius parasiticus*).

Williams, Capt. B. A., schooner Centennial. Scallop shell and pebbles with barnacles, bryozoans, and sea-corn adhering.

Wilson, John I., schooner Otis D. Dana. Specimens of pomarine jæger (*Stercorarius pomatorhinus*); from George's Bank.

Wonson, Everett P. A collection of shells, barnacles, corals, &c.; from Newfoundland and George's Bank.

Wasson, John, United States Surveyor-General, Arizona. Collection of ores and minerals from various mines in Arizona.

Watkins, Joseph C. Small collection of fragmentary bones, pottery, arrow-heads, and fine stone pipe; from mound in Missouri.

Webb, Capt. Henry. (See Washington, D. C., United States Fish Commission.)

Wells, Capt. William N. (See Washington, D. C., United States Fish Commission.)

Welsh, Capt. James. (See Washington, D. C., United States Fish Commission.)

Welsh, Morris. (See Washington, D. C., United States Fish Commission.)

Welsher, H. W. Four specimens of whitefish (*Coregonus albus*); from Madison Lake, Wisconsin.

Werner, Johann, children of. Arrow-head and copper nodule; from Wisconsin.

Wheeler, C. Le R. Specimens of stone implements; from New York.

Wheeler, Lieut. George M., U. S. A. (See Washington, D. C., War Department.)

Whitall, Tatum & Co., Philadelphia. Samples of glass jars.

White, Artemas. Copper celt, slate arrow-heads, and minerals; from New York.

Whiting, Henry. (See Washington, D. C., United States Fish Commission.)

Whiting, Dr. Robert, U. S. N. Copper idol; from the valley of the Rimac, Peru.

Whitman, George P. (See Washington, D. C., United States Fish Commission.)

Whitmore, Hon. A. H. Young sturgeon; from Verona, Me.

Whitmore, Joshua. Lamprey; from Bucksport, Me.

Whitney, L. Flint knives, arrow-heads, and stone ax; from Illinois.

Whitney, Dr. W., U. S. A. Stone axe; from New Mexico.

Whittaker, E. E. Three samples of ore; from Oregon.

Wiggins, Fred. B. Living snake (*Heterodon*); from Virginia.

Wiggins, John B. Three boxes of aboriginal soapstone vessels; from Virginia.

Wilcox, Dr. T. E., U. S. A. Bottle of alcoholic reptiles; from Indian Territory.

Wilder, General J. F. Stone figure-head, pipes, and other valuable relics.

Willard, C. C. Fresh specimen of Rocky Mountain sheep; from Wyoming.

Willetts, Joseph C. Two specimens of lake-trout; from Skaneateles Lake, New York.

Williams, Benjamin. Box of stone implements; from Michigan.

Williams, Capt. B. A. (See Washington, D. C., United States Fish Commission.)

Williamson, Hon. G. A., United States Minister, Guatemala. Box of ethnological and geological specimens; from Guatemala.

Wilson, John I. (See Washington, D. C., United States Fish Commission.)

Wilson, W. M. Collection of living reptiles; from Prince George's County, Maryland.

Wiltheis, C. T. Box of stone relics; from Ohio.

Wittman, E. Box of Cincinnati Group fossils.

Wonson, Everett P. (See Washington, D. C., United States Fish Commission.)

Wood, A. S. Civet cat (*Bassaris astuta*); from Oregon.

Wood, Dr. Preston. Specimens of stone implements; from Illinois.

Wood, Dr. William. Specimen of *Lota maculosa;* from Connecticut.

Woodward, A. J. Shell of turtle; from Otter Creek, Florida.

Woolley, C. W. Specimens of the tobacco-worm moth; from Illinois.

Wooster, A. F. Specimens of arrow-heads and eggs of robin and chicken-sparrow.

Wooster, L. C. Package of Upper Cretaceous fossils; from the Cache la Poudre River, Colorado.

Yarrow, Dr. H. C. Mummy of Arapahoe child and surroundings; from Sidney, Nebr.

Zeledon, José C. Six boxes of general natural history and ethnological collections; from Costa Rica.

Unknown. Corals; scales of tarpum, Indian stone tube, amethystine crystal; specimens of mule-killer (*Thelyphonus*); specimen of coal; snake; stone relics from West Virginia; insect; box of fossils from Lawrence, Kans.; fossil plant; living black-snakes (*Bascanium constrictor*); living helgramite; from Virginia.

INTERNATIONAL EXHIBITION.*

1876.

Certificate of Award

To the Smithsonian Institution, for Hon. Thomas Donaldson, Collector.

Collection of Ores.

No. 1.—*Group* 1.

UNITED STATES CENTENNIAL COMMISSION,
(In accordance with the Act of Congress)
Philadelphia, September 27, 1876.

A. T. Goshorn,
Director General.

John L. Campbell,
Secretary.

Jos. R. Hawley,
President.

STATISTICS OF EXCHANGES.

BOXES SENT ABROAD IN 1878.

Country.	Smithsonian exchanges.	Government exchanges.	Total.
	No. of boxes.	*No. of boxes.*	
AMERICA.			
Argentine Confederation	....	4	4
Brazil	2	2	4
British Guiana	1	....	1
Canada	....	4	4
Chili	1	2	3
Hayti	....	2	2
Mexico	2	2	4
Peru	1	....	1
Venezuela	1	2	3
ASIA.			
Japan	2	2	4
Syria	1	....	1
AUSTRALIA.			
New South Wales	1	2	3
New Zealand	2	2	4
Queensland	1	2	3
South Australia	1	2	3
Tasmania	1	2	3
Victoria	2	2	4
EUROPE.			
Belgium	6	2	8
Denmark	6	....	6
France	40	2	42
Germany	60	17	77
Great Britain	54	4	58
Greece	....	2	2
Holland	6	2	8
Italy	10	....	10
Norway	4	2	6
Portugal	3	2	5
Russia	7	2	9
Spain	3	2	5
Sweden	6	2	8
Switzerland	12	2	14

*Omitted from the Report for 1876, page 83.

RECAPITULATION.

Country.	Smithsonian exchanges.	Government exchanges.	Total.
	No. of boxes.	*No. of boxes.*	
America	8	18	26
Asia	3	2	5
Australia	8	12	20
Europe	217	41	258
Total	236	73	309

NOTE.—No. of boxes, 309; bulk, in cubic feet, 2,160; weight, in pounds, 69,220, containing fourteen thousand six hundred and forty-eight miscellaneous packages, of which 60 contained specimens of natural history.

PACKAGES RECEIVED BY THE SMITHSONIAN INSTITUTION FROM EUROPE, &C., FOR DISTRIBUTION IN AMERICA.

	1877.	1878.
ALABAMA.		
Tuscaloosa:		
Alabama University	......	4
ARIZONA.		
Prescott:		
Territorial Library	1	......
ARKANSAS.		
Little Rock:		
State Library	......	10
CALIFORNIA.		
Berkeley:		
University of California	4	......
Sacramento:		
Agricultural and Horticultural Society	2	......
California Institution	1	......
California Institution for the Deaf and Dumb and Blind	1	......
Geological Survey of California	......	1
State Agricultural Society	1	1
San Francisco:		
California Academy of Sciences	60	61
California Historical Society	1	......
Mayor of the city of San Francisco	2	1
Mechanics' Institute	1	......
Stockton:		
Society of Natural History	1	......
State Insane Asylum	1	......
COLORADO.		
Colorado Springs:		
El Paso County Library Association	1	......
Denver:		
State Library	1	......
CONNECTICUT.		
Hartford:		
American Philological Association	......	1
Connecticut Society of Natural History	1	......
Connecticut State Agricultural Society	1	1
Retreat for the Insane	1	......
Society of Natural Sciences	......	1
State Board of Agriculture	1	8
State Library	1	......
Young Men's Institute	3	2
Watkinson Library of Reference	......	1
Middletown:		
Hospital for the Insane	1	......
New Haven:		
American Journal of Science and Arts	39	35
American Oriental Society	19	16
Connecticut Academy of Arts and Sciences	92	119
Sheffield Scientific School	......	1
Yale College	30	34
DISTRICT OF COLUMBIA.		
Georgetown:		
Georgetown College	7	4
Hillsdale:		
Pioneer School	1	......
DISTRICT OF COLUMBIA—Continued.		
Washington:		
Agriculture, Department of	107	113
American Medical Association	9	22
Board of Public Schools	......	1
Botanic Garden	1	......
Coast Survey	46	61
Census Bureau	6	4
Columbia Institution for the Deaf and Dumb	1	2
Columbian University	3	6
Corcoran Gallery of Art	......	1
Education, Bureau of	10	6
Engineer Bureau	9	10
Fish Commission	2	5
Geological Survey of the Territories	83	96
Government Hospital for the Insane	1	......
Hydrographic Office	13	14
Indian Commissioners, Office of the	3	......
Interior Department	9	10
Land Office	9	7
Library of Congress	32	33
Light-House Board	2	......
Medical Society of the District of Columbia	1	1
National Academy of Sciences	43	70
Nautical Almanac Office	4	14
Naval Observatory	50	54
Navigation, Bureau of	3	1
Navy Department	2	4
Ordnance Office	2	3
Patent Office	99	120
Paymaster-General, U. S. A	......	1
Philosophical Society	3	......
President of the United States	1	......
Signal Office	26	28
Statistics, Bureau of	13	16
Surgeon-General's Office	88	108
Swedish and Norwegian Legation	2	......
Treasury Department	1	2
War Department	6	15
GEORGIA.		
Athens:		
University of Athens	1	......
Augusta:		
Horticultural Society	1	......
Savannah:		
Historical Society of Georgia	2	5
ILLINOIS.		
Aurora:		
Literary and Historical Society	1	......
Bloomington:		
Illinois Museum of Natural History	3	......
Carbondale:		
Southern Illinois Normal University	......	6
Chicago:		
Chicago Academy of Science	55	78
Chicago Board of Trade	1	......
Chicago Historical Society	1	......
Chicago Public Library	14	9
Dearborn Observatory	5	5

Packages received by the Smithsonian Institution, &c.—Continued.

	1877.	1878.
ILLINOIS—*Continued.*		
Mayor of the city of *Chicago*	1	
National Live Stock Journal	1	
Public School Library		5
University of Chicago		4
Elgin:		
Northern Hospital for the Insane	2	
Evanston:		
Northwestern University	1	
Galesburg:		
Lombard University	1	
Jacksonville:		
State Hospital for the Insane	1	
Moro:		
American Pomological Society		3
Normal:		
Illinois Natural History Society and Museum		4
Ottawa:		
Academy of Natural Sciences	1	1
Rantoul:		
Rantoul Literary Society	1	
Springfield:		
State Board of Agriculture	3	
INDIANA.		
Bloomington:		
Indiana University	1	
Greencastle:		
Indiana Asbury University	1	
Indianapolis:		
Geological Survey of Indiana		10
Historical Society	1	
Indiana Horticultural Society		1
Institution for the Education of the Blind		1
Public Library		1
IOWA.		
Burlington:		
Iowa Historical and Genealogical Institute	1	
Davenport:		
Davenport Academy of Sciences	15	52
Decorah:		
Norwegian Lutheran College	4	
Des Moines:		
Department of Public Instruction	3	
State Library		1
Grinnell:		
Grinnell University		1
Iowa City:		
Director Iowa Weather Service		1
Iowa State University	21	18
Laboratory of Physical Science		1
Mount Pleasant:		
Asylum for the Insane	1	
KANSAS.		
Baldwin City:		
Baker University	1	
Ossawatomie:		
Kansas Insane Asylum	1	
Topeka:		
Kansas Natural History Society	1	
KENTUCKY.		
Frankfort:		
State Library	1	
Hopkinsville:		
Western Lunatic Asylum	1	
Lexington:		
Eastern Lunatic Asylum	1	
Kentucky University	1	
Louisville:		
Mayor of the city of Louisville	1	1
Public Library	3	
University of Louisville	5	
Russellville:		
Logan Female College		1
LOUISIANA.		
Baton Rouge:		
State University	3	
LOUISIANA—Continued.		
Clinton:	1	
Louisiana Insane Asylum		
New Orleans:		2
Athenée Louisianais	1	
Insane Asylum	1	2
Mayor of the city of New Orleans		
New Orleans Academy of Natural	20	32
Sciences	8	8
State Library		2
University of Louisiana		
MAINE.		
Augusta:		
Commissioner of Fisheries of the State of Maine	2	1
Maine Hospital for the Insane	1	
Natural History and Geological Society		2
State Board of Agriculture	2	
Brunswick:		
Bowdoin College	11	4
Historical Society of Maine	7	2
Calais:		
Calais High School and Academy	2	
Lewiston:		
Androscoggin Natural History Society	1	
Norway:		
High School and Academy	1	
Portland:		
Maine Agricultural Society	1	
Portland Society of Natural History	28	40
Waterville:		
Colby University	4	3
MARYLAND.		
Annapolis:		
St. John's College		3
United States Naval Academy	7	4
Baltimore:		
Baltimore City College	1	
Johns Hopkins University	6	8
Maryland Academy of Science	1	3
Maryland Asylum for the Insane	1	
Maryland Historical Society	12	3
Maryland Institute		1
Mayor of the city of Baltimore	2	1
Peabody Institute	7	10
St. Paul's Lyceum and Library Association	4	
University of Maryland	1	
MASSACHUSETTS.		
Amherst:		
Amherst College	7	6
Andover:		
Theological Seminary		1
Boston:		
American Academy of Arts and Sciences	137	182
American Gynecological Society		4
American Social Science Association	2	
American Statistical Association	14	11
American Unitarian Association	1	
Board of State Charities	3	
Boston Art Club	1	1
Boston Athenæum	3	3
Boston Hospital	1	1
Boston Medical and Surgical Journal	12	11
Boston Microscopical Society	1	
Boston Society of Natural History	168	166
Bowditch Library	1	4
Department of Public Instruction		1
Institute of Technology		3
Massachusetts Asylum for the Blind		1
Massachusetts Board of Education	1	1
Massachusetts Historical Society	10	2
Mayor of the city of Boston	2	1
Medical and Surgical Journal	3	
New England Historic Genealogical Society	6	4
North American Review	1	
Public Library	31	30

Packages received by the Smithsonian Institution, &c.—Continued.

	1877.	1878.
MASSACHUSETTS—Continued.		
Science Observer	......	1
State Board of Agriculture	3	3
State Board of Charities	......	1
State Board of Health	9	5
State Library	12	7
Cambridge:		
Cambridge Philosophical Society	1	......
Entomological Club	2	1
Harvard College	39	47
Harvard College Herbarium	2	1
Harvard College Observatory	22	34
Museum of Comparative Zoology	80	88
Nuttall Ornithological Club	......	1
Peabody Museum of American Archæology	4	......
Jamaica Plains:		
Bussey Institute	5	12
Leicester:		
Leicester Public Library	......	2
Newton Centre:		
Theological Institution	5	......
Pennikese Island:		
Anderson School of Natural History	......	4
Salem:		
American Association for the Advancement of Science	43	47
American Naturalist	13	17
Essex Institute	76	81
Peabody Academy of Sciences	76	89
North Church and Society	......	1
Taunton:		
State Lunatic Asylum	1	......
Wellesley:		
Wellesley College	7	......
Williamstown:		
Williams College	4	......
Worcester:		
American Antiquarian Society	19	11
MICHIGAN.		
Ann Arbor:		
Herbarium of the University of Michigan	1	......
Observatory	9	10
University of Michigan	7	......
Coldwater:		
Michigan Library Association	......	9
Detroit:		
Michigan State Agricultural Society	12	5
Kalamazoo:		
Asylum for Insane	1	......
Lansing:		
Michigan State Board of Health	3	......
MINNESOTA.		
Duluth:		
Scandinavian City Library	1	......
Minneapolis:		
Minnesota Academy of Natural Sciences	8	8
University of Minnesota	......	1
Saint Peter:		
Hospital for the Insane	1	......
Saint Paul:		
Minnesota Historical Society	10	6
MISSISSIPPI.		
Oxford:		
University of Mississippi	......	2
MISSOURI.		
Columbia:		
University of Missouri	6	......
Fulton:		
State Lunatic Asylum	1	......
Glasgow:		
Morrison Observatory	......	1
Saint Louis:		
Geological Survey of Missouri	4	6

	1877.	1878.
MISSOURI—Continued.		
Mayor of the city of Saint Louis	2	1
Public Library	1	1
Saint Louis Academy of Science	100	117
Saint Louis University	2	1
State Board of Agriculture	1	2
Washington University	3	......
NEBRASKA.		
Lincoln:		
University of Nebraska	1	......
NEW HAMPSHIRE.		
Concord:		
Department of Agriculture	2	......
New Hampshire Historical Society	4	3
State Agricultural Society	4	......
State Lunatic Asylum	1	......
Hanover:		
Dartmouth College	7	6
NEW JERSEY.		
Hoboken:		
Stevens Institute of Technology	7	9
Newark:		
New Jersey Historical Society	7	......
New Brunswick:		
Geological Survey of New Jersey	5	6
Natural History Society	1	......
Princeton:		
College of New Jersey	21	23
Observatory of College of New Jersey	......	1
Trenton:		
State Lunatic Asylum	1	......
NEW YORK.		
Albany:		
Adirondack Survey Office	4	3
Albany Institute	15	15
Dudley Observatory	16	26
New York State Agricultural Society	15	19
New York State Library	50	60
New York Medical Society	2	1
New York State Museum of Natural History	4	7
New York State University	5	6
Blackwell's Island:		
New York City Lunatic Asylum	1	......
Brooklyn:		
Long Island Historical Society	1	2
Mayor of the city of Brooklyn	1	......
Buffalo:		
Buffalo Historical Society	1	1
Buffalo Medical Association	1	......
Buffalo Society of Natural Sciences	55	73
Observatory	1	......
Clinton:		
Hamilton College	1	......
Litchfield Observatory	4	12
Cornwall:		
Cornwall Library	......	1
Geneva:		
Hobart College	......	2
Hamilton:		
Madison University	1	......
Ithaca:		
Cornell College	5	6
New York:		
American Chemical Society	......	3
American Chemist	3	3
American Christian Commission	4	......
American Ethnological Society	......	1
American Geographical Society	63	60
American Institute	11	15
American Institute of Architects	13	7
American Library Journal	1	......
American Microscopical Society	1	1
American Museum of Natural History	12	14
American Numismatic and Archæological Society	2	......

Packages received by the Smithsonian Institution, &c.—Continued.

	1877.	1878.
NEW YORK—Continued.		
American Public Health Association	2	2
American Society of Civil Engineers	14	7
Anthropological Institute of New York	......	6
Astor Library	18	18
Bloomingdale Asylum for the Insane	1	......
Board of Health of the city of New York	2	......
Columbia College	4	2
Commissioners of Central Park	1	......
Engineering and Mining Journal	18	12
Insurance Department	2	......
Manufacturer and Builder	13	7
Mayor of the city of New York	1	1
Medical Journal	1	......
Medical Recorder	1	......
Mercantile Library Association	4	2
Metropolitan Board of Health	1	......
Metropolitan Museum of Art	1	1
New York Academy of Medicine	3	4
New York Academy of Sciences	81	100
New York Historical Society	1	6
New York Meteorological Observatory	......	11
Observatory	1	......
Sanitarian	14	10
School of Mines	15	16
Scientific American	2	1
Scottish American Journal	2	1
Swedenborg Society	1	......
Swedish-Norwegian Consulate	2	......
United States Sanitary Commission	6	5
University of the City of New York	12	6
Van Nostrand's Eclectic Engineering Magazine	2	1
Poughkeepsie:		
Vassar College	4	1
Rochester:		
Theological Seminary	......	1
Schenectady:		
Union College	3	......
Utica:		
State Lunatic Asylum	1	1
West Point:		
Observatory	1	......
United States Military Academy	1	3
OHIO.		
Ashtabula:		
Anthropological Society	......	1
State Archæological Society	1	......
Athens:		
Ohio University	1	......
Cincinnati:		
American Medical College	1	......
Cincinnati Observatory	17	25
Cincinnati Quarterly Journal of Science	3	2
Historical and Philosophical Society	1	......
Longview Asylum for the Insane	1	......
Mayor of the city of Cincinnati	2	......
Mercantile Library	......	1
Natural History Society	2	2
Public Library	1	3
University of Cincinnati	3	3
Young Men's Mercantile Library	3	......
Cleveland:		
Academy of Natural Sciences	1	......
Columbus:		
Geological Survey of Ohio	5	7
Ohio State Board of Agriculture	18	57
Ohio State Library	9	9
Delaware:		
Museum of Wesleyan University	1	......
Ohio Wesleyan University	1	......
Gambier:		
Kenyon College	......	1
North Bend:		
Ohio Horticultural Society	......	8
Urbana:		
Urbana University	1	......

	1877.	1878.
OHIO—Continued.		
Yellow Springs:		
Antioch College	3	......
PENNSYLVANIA.		
Allegheny:		
Allegheny Observatory	8	4
Society of Natural Sciences	1	......
Carlisle:		
Belles-Lettres Society	1	......
Dickinson College	7	......
Chester:		
Crozer Theological Seminary	......	1
Easton:		
American Institute of Mining Engineers	11	11
Lafayette College	......	2
Germantown:		
Germantown Library Association	2	1
Harrisburg:		
Medical Society of the State of Pennsylvania	2	......
State Library	4	1
Philadelphia:		
Academy of Natural Sciences	146	200
American Entomological Society	21	22
American Journal of Conchology	3	4
American Pharmaceutical Association	31	28
American Philosophical Society	108	145
Board of Health	1	......
Board of Public Education	3	4
Central High School	2	1
Commissioners of Fairmount Park	2	......
Dental Cosmos	1	......
Director of the Mint	......	1
Franklin Institute	28	36
Friends' Book-Store	1	......
Geological Survey of Pennsylvania	4	4
Girard College	......	3
Historical Society of Pennsylvania	10	5
Institution for the Deaf and Dumb	......	1
Jefferson Medical College	2	......
Library Company	2	1
Mayor of the city of Philadelphia	2	1
Medical Times	14	10
Mexican Commission	2	......
Observatory of Girard College	5	2
Office of Gray's Atlas	1	......
Pennsylvania Hospital	1	1
Pennsylvania Hospital for the Insane	1	......
Philadelphia Society for the Promotion of Agriculture	1	......
Social Science Association	......	1
Stacey Stone Dressing Machine Company	1	......
University of Pennsylvania	2	4
Wagner Free Institute of Science	14	10
Zoological Society	5	18
Pittsburg:		
National Iron and Steel Publishing Company	3	......
South Bethlehem:		
Lehigh University	2	3
RHODE ISLAND.		
Providence:		
Brown University	5	2
City Registrar's Office	......	2
Rhode Island Historical Society	4	2
Rhode Island Society for the Encouragement of Domestic Industry	1	......
SOUTH CAROLINA.		
Charleston:		
Charleston Library Society	3	1
Charleston Medical Journal and Review	1	......
Charleston Museum of Natural History	......	1

Packages received by the Smithsonian Institution, &c.—Continued.

	1877.	1878.
SOUTH CAROLINA—Continued.		
Charleston Observatory	1	
Elliott Society of Natural History	11	20
South Carolina Historical Society	2	
South Carolina Medical Association	3	
Columbia:		
University of South Carolina	3	1
Lexington:		
Theological Seminary of the Evangelical Lutheran Club		1
TENNESSEE.		
Knoxville:		
East Tennessee University	2	
Philomathean Society	1	
Lebanon:		
Cumberland University	4	
Nashville:		
Hospital for the Insane	3	
Tennessee Historical Society	1	
University	5	
TEXAS.		
Austin:		
State Library	1	
University of Texas		1
Chapel Hill:		
Soule University	4	2
VERMONT.		
Barnet:		
Vermont Historical and Antiquarian Society	1	
Brattleborough:		
Vermont Asylum for Insane	1	
Burlington:		
University of Vermont	6	2
Castleton:		
Orleans County Society of Natural Sciences	26	33
Montpelier:		
State Cabinet of Natural History	1	
State Library	5	3
VIRGINIA.		
Charlottesville:		
University of Virginia	14	3
Hampden Sidney:		
Hampden Sidney College	1	
Norfolk:		
Agricultural Society	1	
Richmond:		
Historical Society of Virginia	1	
Medical Society of Virginia	3	1
State Library	6	1
WISCONSIN.		
Appleton:		
Lawrence University	1	
Galesville:		
Galesville University	1	
Inmansville:		
Wisconsin Scandinavian Society	2	
Janesville:		
Wisconsin Institute for the Education of the Blind		1
Madison:		
State Historical Society of Wisconsin	10	9
State Library	2	2
Superintendent of Public Instruction	1	
University of Wisconsin	3	2
Washburn Observatory		1
Wisconsin Academy of Arts and Sciences	31	32
Wisconsin State Agricultural Society	19	19
Milwaukee:		
Milwaukee University	3	
WISCONSIN—Continued.		
Natural History Society	3	9
Skandinaviske Presseforning	1	
Neenah:		
Scandinavian Library	3	
Oshkosh:		
Northern Hospital for the Insane	1	
BRITISH AMERICA.		
Fredericton, New Brunswick:		
University of New Brunswick		1
Halifax, Nova Scotia:		
Nova Scotian Institute of Natural Sciences	9	3
Hamilton, Ontario:		
Scientific Association		4
Kingston, Ontario:		
Botanical Society of Canada	1	
Observatory		1
Queen's College	2	
Milltown, St. Stephen's, New Brunswick:		
Public Library	5	
Montreal, Quebec:		
Entomological Society	2	
Geological Survey of Canada	10	13
Mayor of the city of Montreal		1
McGill College	4	
Mechanics' Institute	1	
Montreal Observatory		1
Natural History Society	19	25
Société d'Agriculture du Bas-Canada	1	1
Ottawa, Ontario:		
Library of Parliament	3	1
Literary and Scientific Society		3
Quebec, Quebec:		
Geographical Society		1
Laval University	4	1
Le Naturaliste Canadien	2	
Literary and Historical Society	13	2
Observatory	1	1
Superintendent de l'Instruction Publique	2	
St. John, New Brunswick:		
Natural History Society		5
Toronto, Ontario:		
Board of Agriculture	2	
Canadian Institute	19	30
Literary and Historical Society	1	1
Meteorological Office	2	4
Museum of Education	3	
Observatory	4	6
School of Practical Science, of Agriculture and Arts	3	
University of Toronto	6	6
INDIVIDUALS.		
Abbe, Prof. C	4	9
Adams, Prof. H		1
Agassiz, Prof. A	11	21
Aikens, M. L. A		1
Alexander, Prof. S	1	1
Allen, J. A	2	3
Allen, H		2
Alvord, General	1	
Ames, Mrs. M. P	2	
Anderson, R. B	1	
Andrews, W. V		1
Angell, J. B		1
Anthony, J. G	1	2
Appleton, N		1
Arch, Col. M	1	
Armstrong, Doctor		1
Ashe, Commander E		1
Ashley, A	1	
Astor, W. B		1
Atkinson, C		1
Atkinson, E	1	
Atwood & Culver, Messrs	1	

Packages received by the Smithsonian Institution, &c.—Continued.

	1877.	1878.
INDIVIDUALS—Continued.		
Austin, Mrs. R. M	1	
Austin, C. F		1
Baird, Prof. S. F	53	59
Bailey, H. B	1	
Baker, Prof. W. S	1	
Ballard, J		1
Bancroft, Hon. G	4	2
Bancroft, H. H	1	
Bannister, H. M	1	1
Barber, E. A		2
Barker, Prof. G. F		1
Barlois, Hon. F. C		1
Barnard, Prof. F. A. P	1	2
Barnard, J. M		1
Barnes, Hon. W	4	6
Barnes, Surgeon-General		1
Barrett, G. H. M		1
Bartlett, Prof. W. H. C	1	
Bassett, H. T	1	
Bascomb, Prof. J	1	
Baxter, Dr. J. W	1	
Bean, Dr. T. H		1
Bebb, M. S	5	
Bell, R	1	
Bennet, J. G		1
Berckmans, J. J	1	1
Berton, ——		1
Bessels, Dr. E	10	23
Bessey, Prof. C. E	1	
Bethune, Rev. C. J. S	2	
Bigelow, F. H		1
Billings, E		1
Binney, W. G	5	7
Blake, Prof. W. P	4	3
Bland, T		3
Blazius, Professor		1
Blodget, L	1	
Boardman, G. A	1	
Boehmer, G. H	1	6
Bolander, Doctor		1
Bors, Consul C	1	
Bowditch, Dr. H	3	
Bowditch, H. T		1
Bowles, G. J		1
Bradbrook, S. G	2	1
Bradley, F. A		1
Bradley, Judge	1	
Bradley, F. H		1
Brady, S		1
Brendel, Dr. F	1	3
Brevoort, J. C	2	
Brewer, Dr. T. M	5	2
Broadhead, G. C	1	1
Brocklesby, Professor		1
Brooks, Maj. T. B	1	
Brown, S	1	
Brown, S. G		1
Brunet, L'Abbé O	1	
Brush, Prof. J. G	5	1
Buchanan, Doctor		1
Buchanan, Dr. A	2	
Bullard, J	1	
Burgens, E		1
Burnham, S. W	2	1
Butler, J. D		1
Butler, G. D	2	
Canby, W. M	1	
Capron, General H	2	
Carpenter, Prof. S	1	
Carey, H. C	1	
Case, L		1
Chalmers, R		1
Chamberlain, J. C		2
Chandler, jr., S. C		1
Chandler, Prof. C. F	5	
Chandler, Prof. W. H	1	
Charlier, E	1	
Chase, Prof. P. E	1	1
Chauveau, Hon. J. P. O	3	
INDIVIDUALS—Continued.		
Cherry, C		1
Claghorn, J. L	1	
Clarke, Prof. F. W		3
Clark, S. F	1	
Claypole, E. W	1	
Cleveland, D	1	
Clinton, W. G	1	1
Coffin, J. H. C	1	
Coffin, S. J	1	1
Cohn, Professor	1	
Comstock, General	1	
Congdon, T. W	1	
Conklin, A	1	
Conrad, Doctor	1	
Cook, G. H	1	1
Cook, J. P	1	
Cook, jr., J. P		1
Cope, E. D	7	12
Coues, Dr. E	8	11
Cox, E. T	12	7
Craftes, Prof. J. M	1	
Cresson, E. T		2
Cushing, F. H		1
Cutting, H. B		1
Dabney, Rev. Professor		1
Dale, Prof. T. N		2
Dall, W. H	31	28
Dalton, Dr. J. C	1	
Dana, E. S	2	
Dana, Prof. J. D	32	40
Dana, jr., Rev. R. H		1
Davidson, Prof. G	3	3
Davis, Rear-Admiral C. H	1	1
Davis, H. E	1	1
Davison, E. F		1
Dawson, Dr. J. W	3	3
Deane, Dr. C		1
Dejardin, P		1
Dike, C	1	1
Dobson, James	1	1
Dobson, John	1	1
Dow, Capt. J. M	4	5
Downes, J	1	
Draper, Dr. D	3	1
Draper, Dr. H	1	2
Draper, Prof. J. W	1	
Draper, L. C		1
Ducatel, Madam	1	
Eads, J. B	1	
Eastman, Prof. J. R	2	1
Eaton, Hon. J		1
Eaton, William S		1
Edwards, H		1
Edwards, W		3
Egleston, Prof. T	5	1
Eisen, Dr. G		2
Elder, Dr. W	1	
Eliot, Prof. C. W	1	
Eliot, S		1
Ellinwood, Dr. E. M		1
Elliot, Doctor	1	
Ellis, J. B	1	
Ellis, F. B		1
Ellis, Rev. G. E		1
Emerson, Prof. B	6	5
Emmons, Judge		1
Endlich, Dr. F. M	3	
Engelmann, Dr. G	2	1
Ericson, Capt. J	2	
Exall, H		1
Farlow, Dr. W. G	2	3
Farquarson, R. J		1
Farskey, Colonel	1	
Fay, S	1	1
Ferrell, Prof. W		2
Fields, D. D		1
Firth, A	2	2
Fish, Hon. H		1
Fisher, Dr. G. J	4	2

Packages received by the Smithsonian Institution, &c.—Continued.

	1877.	1878.
INDIVIDUALS—Continued.		
Fiske, W	1	
Fiss, G. W	1	1
Fitch, A		1
Fitch, G. T	1	
Fleischer, F	1	
Flügel, W		1
Force, W. Q	1	
Ford, S. W	1	3
Foreman, Dr. E	1	1
Fowler, W. C	1	
Fremont, General J		16
Fuller, H. W		1
Gabb, Dr. W. M	1	1
Gatschet, N. S	1	1
Genth, Dr. F. A	3	
Gibbs, W	1	1
Gilbert, G. K	3	2
Gill, Prof. T	5	5
Gilman, Prof. D. G		1
Gilpin, Governor W		1
Goodall, A. G		1
Goode, G. B		2
Goodfellow, E	1	
Goshorn, A. T	1	
Grant, Maj. C. C		1
Gray, Prof. A	20	17
Greene, Rev. E. L	2	
Gregory, J. M		1
Grote, A. R		1
Gurman, Dr	1	
Guttenberg, G	1	
Guyot, Prof. A	10	8
Habel, Doctor		1
Hagen, Dr. H. A	2	5
Haldeman, S. S	1	1
Hall, Prof. A		2
Hall, Prof. J	6	16
Hammond, Dr. W. A		2
Hanson, P		1
Harding, C. L	1	1
Harding, E	1	1
Harding, G. W	1	1
Hare, Prof. H. B	1	
Harkness, Prof. W	1	3
Harper & Brothers	1	
Harrington, Prof. M. W	1	
Hartranft, Hon. J. F	1	
Hawley, General J. B	1	
Hayden, Dr. F V	116	125
Hayes, Dr. J. J	1	
Heinzer, C	1	
Henry, Prof. J	32	11
Heizer, J. M	1	
Herbert, G	1	
Higgins, E. S	1	1
Hilgard, E. W	1	
Hilgard, Prof. J. E	1	1
Hill, G. W	1	1
Hinrichs, Prof. G	8	18
Hilton, W		1
Hitchcock, Prof. C. H	1	
Hitchcock, Prof. R. D		1
Hitz, J		1
Holden, Prof. E. S	3	4
Holden, W		1
Holley, A	1	
Holmes, W. H	2	
Holmes, D. S		1
Holmes, N		1
Horn, Dr. G. H		1
Horsford, Prof. E. N	2	
Hough, F. B	8	4
Hovey, Prof. A	1	
Howe, E. C		1
Howells, W. D	2	
Hoyt, J. W		1
Humphreys, General A. A	1	2
Hun, T		1
Hunnies, A		1
Hunt, Prof. T. S	2	1
INDIVIDUALS—Continued.		
Hyatt, Prof. A	4	5
Isaacs, S. E. U		1
Jackson, W. H	2	
Jagger, Bishop		1
Jarvis, Dr. E	34	21
Jewett, Col. E	1	
Johnson, J. A	1	
Johnson, O. C	1	
Johnson, S. W	1	
Jones, C. C		1
Jones, M. E	1	1
Joly, H. G	1	
Joor, Dr. J. F		2
Joplin	5	
Joy, Prof. C. N		1
Joyce, Dr. R		1
Kaiser, Dr. P. D	1	
Kendall, Prof. O		1
Kennedy, J. C. G		1
Kerr, W. C	1	
Keyes, E. W	1	
King, C	6	9
Kingsley, T. S		1
Kingsley, W. L		1
Kingston, Prof. G. T		2
Kirtland, Dr. J. P	1	
Knight, E	1	
König, Doctor		1
Könings, Rev. A		1
Kolkin, Mr	1	
Koren, Rev. V	1	
Lamphere, A. T		1
Landreth & Sons	1	
Lane, G. M		1
Langley, Prof. J. P		1
Lanman, C. R	3	
Lapham, Dr. S. G	1	
Lawrence, G. N		5
Lawrence, Hon. W. B		1
Lea, Dr. I	14	19
Lea, C	1	
LeClair, T. S	1	
LeConte, Dr. J	4	9
LeConte, Prof. Joseph	1	1
Lee, Admiral S. P		2
Lee, Col. F. L	2	
Lees, J. S	1	
Leidy, Prof. J	8	20
Lemmon, J. G	1	
Leonard, Prof. T. M		3
Lesley, Prof. J. P	2	5
Lesquereux, Prof. L	2	4
Leyman, T	1	
Lindermann, H. R	1	
Longfellow, H		3
Longfellow, F. W	2	
Longstreth, F. W	1	
Loomis, Prof. E	7	14
Lovering, Prof. J	3	2
Lyman, Dr. B. T	2	
Lyman, Prof. C. S		2
Lyman, T		5
McCagg, E. B		1
Macoun, Prof. J		2
Magelsen, Rev. C	1	
Mallet, J. W	1	
Manigault, G. E	6	5
Marcy, Dr. O		1
Marsh, Prof. F. A	1	
Marsh, Prof. O. C	9	14
Mason, Prof. O. T	1	
Master, A		1
Matile, G. A		1
Matthews, G. F	2	1
Mayes, Prof. A. M		1
Mechan, J. H. M	1	
Mechan, Dr. T	1	
Meigs, Dr. J. A	4	5
Merriam, G. & C	1	
Merriman, Dr. M		1

Packages received by the Smithsonian Institution, &c.—Continued.

INDIVIDUALS—Continued.	1877.	1878.
Meyer, J. E		2
Michelet, N	1	
Miller, S. A		3
Milner, Mr		1
Minot, Professor		1
Mitchel, J. E	1	
Mitchell, H		1
Mitchell, Dr. S. Weir	1	
Morgan, Dr. L	1	
Morman, A. T		1
Morris, Prof. G. S	1	
Morris, Dr. J. G		1
Morse, Dr. E. S	3	
Morton, Dr. H. H	1	1
Motley, J. L		2
Munroe, F. H	1	
Muns, Rev. B. J	1	
Myer, Brig. Gen. A. J	1	4
Neumögen, B	1	2
Newberry, Dr. J. S	4	6
Newcomb, Prof. S	8	15
Newton, Prof. H. A	1	4
Newton, General J	1	
Nicholson, W. L		1
Nichos, Prof. R	1	
Nipher, Prof. F. E		1
Nivens, J. F		1
Nolan, E. J	1	
Northrop, Hon. B. E	1	1
Norton, Prof. W. A	1	
Norton, Prof. C. E		3
Nourse, Prof. J. E	2	2
Olds, L. P	1	
Oliver, Prof. J. E	1	
Olmstead, Rev. L	1	3
Olsen, A	1	
Ordway, Dr. A		1
Osten-Sacken, Baron R	7	
Ottesen, Rev. J. A	1	
Outerbridge, A. A	1	
Paaren, Dr. A. H	2	5
Packard, Dr. A. S	8	
Packard, jr., Dr. A. S		13
Paine, Dr. M	1	
Palpey, J. G	1	
Parker, Dr. P	4	
Parkman, F	1	2
Parsons, Prof. T	1	
Patterson, Capt. C. P		1
Peale, Dr. A. C	2	
Peale, T. R		1
Pearson, J	11	14
Peck, C. H	1	1
Peckham, Prof. S. F	4	
Peirce, Prof. B	1	6
Perkins, C. C	1	
Perry, Dr. A. W	1	
Peters, Dr. C. H. F	4	4
Pettersen, Dr. F. V		1
Pettit, H	1	
Philbrick, J. D		1
Pickard, J. L		1
Pickering, Dr. C	2	
Pickering, Prof. E. C	1	1
Pierrepoint, W. C		1
Pinkham, Prof. G. L		1
Pitkin, Doctor	1	
Poesche, T		3
Porse, B. P		1
Porter, Prof. S. C	1	
Pourtales, L. F. de	2	5
Powalky, Dr. C	1	
Powell, Maj. J. W	11	3
Powers, H. A		1
Prime, Dr. F	1	
Prime, T	2	1
Pringle, C. G		1
Prout, Dr. H. A		1
Pumpelly, Prof. R		1

INDIVIDUALS—Continued.	1877.	1878.
Putnam, F. W	1	3
Putnam, Doctor	1	
Quinby, Dr. W. F		1
Quincy, Hon. J		1
Randolph, B	1	
Rassmussen, Rev. P. A	1	
Rau, Dr. C	5	3
Redfield, Professor	1	1
Reed, E. W		1
Reis, N. T		1
Reverbon, J		2
Reynolds, Miss M		1
Rhees, William J	1	
Richardson, Dr. W. T		1
Ridgway, R	4	
Riley, C. N	2	3
Roberts, G	1	1
Robinson, R. W	1	1
Rodgers, Rear-Admiral J	1	2
Rodgers, Prof. R. E	1	
Roessler, A. R		3
Rogers, Prof. F	1	1
Rogers, Prof. W. B	2	1
Rood, Prof. D. N	1	
Rood, Prof. O. N	1	1
Rosengarten, J. G		1
Ross, A. M	1	
Roy, Mrs. J		2
Rust, F. N		1
Rutherford, L. M	1	4
Safford, Prof. J		1
Safford, Prof. T. H	1	4
Salisbury, Prof. E. E	2	1
Sanborn, F. B		1
Sandford, J. E	1	3
Sands, Rear-Admiral B. F		2
Sargent, C. S		1
Saussure, W. de		4
Sayre, Prof. L. A	1	
Schaff, P		2
Schott, C. A	1	1
Schroeder, Mrs. E		1
Schumacher, P		1
Schurz, Hon. C		1
Schuster, M		1
Scott, Colonel	1	
Scudder, S. H	7	6
Sellers, W	1	
Selwyn, A. R. G	2	
Sequard, Dr. C. Brown	1	
Seyffarth, Dr. G	1	
Shaler, Prof. N. S	1	
Sheidy, L. P	1	
Shugley, J	1	
Sibley, J. L		1
Silliman, Prof. B	11	11
Simon, Prof. W	1	
Slater, jr., H. N	1	1
Smith, A	1	
Smith, Alex		1
Smith, B. S	2	
Smith, Prof. H. L	2	4
Smith, Prof. J. L	4	1
Smith, Prof. S. I	1	
Smith, Prof. S		2
Smith, W. H	1	
Snow, Dr. E	4	10
Soldan, F. P		1
Squier, E. G	1	
Stallo, Judge F		1
Stanley, A. & F		1
Stearns, R. E. C	1	1
Steel, T		1
Steere, Prof. J. B	1	2
Sterling, C		1
Stevenson, J. J	1	
Stewardson, T		1
Stewart, E. F	1	
Stirling, C	1	

Packages received by the Smithsonian Institution, &c.—Continued.

	1877.	1878.
INDIVIDUALS—Continued.		
Stockwell, J. W		1
Stone, Dr. O		2
Stover, Prof. F	1	
Strecker, H	1	3
Suckow, B. N	1	
Swallow, Prof. G. C		1
Sweet, E. G		1
Taft, R. C	1	1
Taylor, Prof. W. B	1	1
Thomas, Prof. C		2
Thomas, S. H		1
Thomson, J. H	13	14
Thompson, Dr. J. H	2	
Todd, D. P	3	1
Toner, Dr. J. M		3
Trowbridge, Prof. J. P	1	
Trowbridge, Prof. W. P	1	
Trumbull, Dr. J. H	1	
Tryon, G. W		2
Tuckerman, Prof. E	11	12
Twing, Rev. Dr	1	
Twining, Prof. A. C		3
Tyler, S	1	
Uhler, Prof. P. R		1
Van der Weyde, Prof. P. H	1	
Van Name, Prof. A	1	
Vasey, Dr. G		1
Verrill, Prof. E. A	5	
Wacksmuth, C	1	1
Waite, Judge	1	
Walcott, C. D		1
Walker, Dr. D	1	
Walker, Prof. F. A	6	7
Walker, J	1	
Walton, J. J	1	
Ward, Prof. A. H		1
Ware, Mrs. M. G	1	
Waring, Col. G. E	1	
Watson, Prof. J. C	1	2
Watson, Prof. S	1	
Weeden, W. B	1	1
Welling, Prof. J. C	1	
Wells, J	1	
Wells, W. H		1
Welsch, J	1	
Werner, Prof. A		1
Weston, H. C	1	1
Wheatley, Prof. C. M		1
Wheeler, Lieut. G. M	6	11
Whetherby, Prof. A. G	1	
White, Dr. C. A	5	7
White, Dr. M. C	1	
Whiting, Commodore W. B		1
Whitney, Prof. J. D	3	6
Whitney, Prof. W. D	10	15
Whittier, J. G	1	
Wibbe, Prof. H		1
Wickham, W. H		1
Wigglesworth, E		1
Wilder, Prof. B. G	1	1
Willey, H	2	2
Willey, O. S	1	
Williamson, S	2	
Wilson, J. M	1	
Winchell, Prof. A		3
Winchell, Prof. N. H		1
Wines, Rev. D		1
Wing, E		1
Winslow, E		1
Wood, W		1
Wordrow, Rev. Professor	1	1
Woodward, Dr. J. J		2
Woolsey, Prof. D	1	
Worthen, Prof. A. H	8	7
Wright, Prof. A. M		1
Wright, Prof. A. W		1
Wright, Prof. R		3
Wurtz, H	1	
Wyman, M		1
Yarnall, Prof. M	1	1
Yarrow, Dr. H. C	6	8
Young, Prof. C. A	2	5
Young, C. B	15	9
Zeledon, Prof. M	1	1

RECAPITULATION.

	1877.	1878.
Total addresses of institutions	392	292
Total addresses of individuals	374	370
Total	766	662
Total number of parcels to institutions	3,868	4,059
Total number of parcels to individuals	1,094	1,233
Total	4,962	5,292

AGENTS FOR TRANSMISSION AND DISTRIBUTION OF SMITHSONIAN EXCHANGES.

Countries.	Shipping agents.	Distributing agents.
Algeria	Compagnie Générale Transatlantique (L. de Bébian), New York.	Commission Française des Echanges Internationaux, Paris.
Argentine Republic	Ed. F. Davison, New York	Museo publico, Buenos Aires.
Australia. (See New South Wales, New Zealand, Queensland, South Australia, Tasmania, Victoria.)		
Austro-Hungary	North German Lloyd, New York and Baltimore.	Dr. Felix Flügel, Leipzig.
Belgium	White Cross Line of Antwerp (Funch, Edye & Co.), New York.	Commission Belge d'Echanges Internationaux, Brussels.
Bolivia	Joseph S. Spinney, New York	University, Chuquisaca.
Brazil	Charles Mackall, vice-consul, Baltimore, Merchants' Line of Steamers (B. R. Borland), New York.	Instituto Historico, Geografico y Ethnografico, Rio Janeiro.
Canada	New York, Alexandria, Washington, and Georgetown steamers.	Geological Survey of Canada, Montreal.
Cape Colonies	Baltimore and Ohio Railroad foreign freight department.	William Wesley, London.
Central America. (See Costa Rica, Guatemala.)		
Chile	H. R. Grace & Co., New York	Universidad, Santiago.
China	Baltimore and Ohio Railroad foreign freight department.	William Wesley, London.
Colombia, United States of.	Pacific Mail Steamship Company, New York.	Sociedad de Naturalistas, Bogota.
Costa Rica	Pacific Mail Steamship Company	University, San José.
Cuba	Havana and West Indian Express (Carrington & Co.), New York.	Prof. F. Poey, Havana.
Denmark	Hamburg-American Steam Packet Company (Kunhardt & Co.), New York.	Kongelige Danske Videnskabernes Selskab, Copenhagen.
Ecuador	A. Flores, New York	Observatorio del Colegio Nacional, Quito.
Egypt	S. L. Merchant & Co., New York	Institut Egyptien, Alexandria.
Finland	Abs, Wyburg, Wasa and Finland Steam Navigation Company, Hull.	
France	Compagnie Générale Transatlantique (L. de Bébian), New York. Boyd & Hincken, New York.	Commission Française des Echanges Internationaux, Paris.
Germany	North German Lloyd (Oelrichs & Co., New York; Schumacher & Co., Baltimore).	Dr. Felix Flügel, Leipzig.
Great Britain	Cunard Line (C. G. Francklyn), New York. Baltimore and Ohio Railroad foreign freight department.	William Wesley, London.
Greece	Consul D. W. Botassi, New York	
Guatemala	Pacific Mail Steamship Company, New York.	Sociedad Economica de Amigos del Pais, Guatemala.
Guiana, British		Queen's College, Georgetown.
Guiana, Dutch	Thomas F. Bixby & Co., Boston	Surinaamsche Koloniaale Bibliotheek, Paramaribo.
Hayti	Atlas Steamship Company (Pim, Forwood & Co.), New York.	Sécrétaire de l'Etat des Relations Extérieures, Port-au-Prince.
Holland. (See Netherlands)		
Iceland	Hamburg-American Steam Packet Company (Kunhardt & Co.), New York.	Kongelige Danske Videnskabernes Selskab, Copenhagen.
India		William Wesley, London.
Italy	Anchor Steamship Line (Henderson & Bro.), New York.	Ulrico Hoepli, Milano.
Jamaica		Royal Society of Arts, Kingston.
Japan	Pacific Mail Steamship Company, New York. Japanese consuls in New York and San Francisco.	Imperial University, Tokio.
Java		Genootschap van Kunsten en Wetenschappen, Batavia.
Liberia	American Colonization Society, Washington.	
Mauritius		William Wesley, London.
Mexico	Juan N Navarro, consul, New York	Museo Nacional, Mexico.
Netherlands	Netherland-American Steamship Navigation Company (H. Cazaux), New York.	Bureau Scientifique (Prof. von Baumhauer), Harlem. Fred. Muller, Amsterdam.
New South Wales	R. W. Cameron & Co., New York	Royal Society of New South Wales, Sydney.
New Zealand	R. W. Cameron & Co., New York	Parliamentary Library, Wellington.

AGENTS FOR TRANSMISSION, &C.—Continued.

Countries.	Shipping agents.	Distributing agents.
Norway	Hamburg-American Steam Packet Company (Kunhardt & Co.), New York.	Kongelige Norske Frederiks Universitet, Christiania.
Peru	Joseph S. Spinner, New York	Biblioteca Nacional, Lima.
Philippine Islands	Spanish consul, San Francisco (offered).	Royal Economical Society, Manila.
Portugal	Consul Gustav Amsink, New York	Ecola Polytechnica, Lisbon.
Queensland	Hon. A. McAllister, Queensland department, London.	Government Meteorological Observatory, Brisbane.
Russia	Wm. Ropes & Co., New York	L. Watkins & Co., St. Petersburg.
Sandwich Islands	Consul Severance, San Francisco	Royal Hawaiian Agricultural Society, Honolulu.
South Australia	R. W. Cameron & Co., New York	Astronomical Observatory, Adelaide.
Spain	Spanish consul, New York	Real Academia de Ciencias, Madrid.
Sweden	Hamburg-American Steam Packet Company (Kunhardt & Co.), New York.	Kongliga Svenska Vetenskaps Akademien, Stockholm.
Switzerland	North German Lloyd (Schumacher & Co.), Baltimore. Consul von Heyman, Bremen.	Bundes Canzlei, Bern.
Syria	J. Chrysoveloni & Co., Liverpool	
Tasmania	Crown agents for the colonies, London.	Royal Society of Tasmania, Hobarton.
Trinidad		Scientific Association, Port of Spain.
Turkey	Turkish Minister, Washington	
Venezuela	C G. de Garmendia, New York	Soc. de Ciencias Fisicas y Naturales, Caracas.
Victoria	R. W. Cameron & Co., New York	Public Library, Melbourne.
West Indies	Thomas Dennison, New York (for Antigua). H. B. Bailey, New York. Wilson & Asmus (for Turks Islands). Thomas Bland, New York. See also Cuba, Jamaica, Hayti.	

ACTS AND RESOLUTIONS OF CONGRESS RELATIVE TO THE SMITHSONIAN INSTITUTION.

FORTY-FIFTH CONGRESS, SESSION II.

PUBLIC RESOLUTION—No. 6.

JOINT RESOLUTION filling an existing vacancy in the Board of Regents of the Smithsonian Institution.

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the existing vacancy in the Board of Regents of the Smithsonian Institution, of the class other than members of Congress, shall be filled by the appointment of NOAH PORTER, of Connecticut, in place of JAMES D. DANA, resigned.

Approved, January 26, 1878.

PUBLIC RESOLUTION—No. 15.

JOINT RESOLUTION filling an existing vacancy in the Board of Regents of the Smithsonian Institution.

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the existing vacancy in the Board of Regents of the Smithsonian Institution, of the class other than members of Congress, shall be filled by the appointment of WILLIAM T. SHERMAN, of the city of Washington, in place of GEORGE BANCROFT, of said city, resigned.

Approved, March 25, 1878.

FORTY-FIFTH CONGRESS, SESSION III.

CHAPTER 21.

AN ACT authorizing the Chancellor of the Smithsonian Institution to appoint an Acting Secretary in certain cases.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That in the case of the death, resignation, sickness, or absence of the Secretary of the Smithsonian Institution, the Chancellor thereof shall be, and he is hereby, authorized to appoint some person as Acting Secretary, who for the time being shall be clothed with all the powers and duties which by law are devolved upon the Secretary, and he shall hold said position until an election of Secretary shall be duly made, or until the Secretary shall be restored to his health, or, if absent, shall return and enter upon the duties of his office.

Approved, January 24, 1879.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE YEAR 1878.

The Executive Committee of the Board of Regents of the Smithsonian Institution respectfully submit the following report in relation to the funds of the Institution, the appropriations by Congress for the support of the National Museum, the receipts and expenditures for both the Institution and the Museum for the year 1878, and the estimates for the year 1879:

Statement of the condition of the funds at the beginning of the year 1879.

The amount originally received as the bequest of James Smithson, of England, deposited in the Treasury of the United States, in accordance with the act of Congress of August 10, 1846		$515,169 00
Residuary legacy of Smithson, received in 1865, deposited in the Treasury of the United States, in accordance with the act of Congress of February 8, 1867		26,210 63
Total bequest of Smithson		$541,379 63
Amount deposited in the Treasury of the United States as authorized by act of Congress, February 8, 1867, derived from savings of income and increase in value of investments		108,620 37
Amount of the bequest of James Hamilton, of Carlisle, Pa., February 24, 1874		1,000 00
Total permanent Smithson fund in the United States Treasury, bearing interest at 6 per cent., payable semi-annually in gold		$651,000 00
In addition to the above, there remains of the extra fund, from savings, &c., in Virginia bonds and certificates, viz:		
Consolidated bonds	$58,700 00	
Deferred certificates	29,375 07	
Fractional certificate	50 13	
Total	88,125 20	
Valued January, 1879, at		34,000 00
Also, the cash balance in the United States Treasury at the beginning of the year 1879		19,632 57
Total Smithson funds, January 8, 1879		$704,632 57

RECEIPTS IN 1878.

Interest on $650,000, for the year 1878, at 6 per cent., gold		$39,000 00
Premium on gold interest, July 1, 1878, at ½ per cent		97 50
Interest on Virginia bonds:		
Sale of coupons by Riggs & Co., for January 1 and July 1, 1878, for $3,522 (December 9, 1878) at 78–79		2,776 34
Interest on Hamilton fund of $1,000 for the year 1878	$60 00	
Premium on gold, July 1, 1878, at ½ per cent	15	
		60 15
Repayment by Library of Congress:		
For advances made for international exchanges in 1877		1,781 00
Balance on hand at the beginning of 1878		25,083 90
Total receipts for the year 1878		$68,798 89

EXPENDITURES IN 1878.

Building, furniture, and fixtures	$4,712 72	
General expenses	18,136 42	
Publications, researches, and explorations	15,732 92	
International literary and scientific exchanges	10,250 41	
Gallery of art	333 85	
		$49,166 32
Cash balance, January 7, 1879		$19,632 57

HAMILTON BEQUEST.

Received from James Hamilton, February 24, 1874, and deposited with the Smithson fund in the Treasury of the United States		$1,000 00
Interest received from February 24, 1874, to December 31, 1878		306 32
Appropriated in 1876 for exploration of cave near Carlisle, Pa	$150 00	
Appropriated in 1878 for exploration of steatite quarry in Virginia	156 32	
		306 32

Statement of expenditures in 1878, in detail.

BUILDING.

Repairs and improvements	$4,346 43	
Furniture and fixtures	366 29	
		$4,712 72

GENERAL EXPENSES.

Meetings of the Board	$399 25	
Lighting the building	260 80	
Heating the building	593 37	
Postage and telegraphing	395 54	
Stationery	797 96	
Incidentals (ice, hauling, insurance, &c.)	642 03	
Salaries (including allowance to family of Professor Henry, $2,812.50)	14,371 96	
Extra clerk hire and labor	200 00	
Books and periodicals	475 51	
		$18,136 42

PUBLICATIONS, RESEARCHES, ETC.

Smithsonian Contributions to Knowledge	$5,523 14	
Miscellaneous Collections	7,432 48	
Annual Report	942 20	
Researches	1,032 13	
Apparatus	121 56	
Laboratory	86 21	
Explorations	595 20	
		15,732 92
Literary and scientific exchanges		10,250 41
Gallery of art		333 85
		$49,166 32

A larger expenditure for repairs of the building than was anticipated was made necessary by a violent and destructive storm which visited Washington last summer by which the finials or caps on some of the towers, and several hundred slates from the roof, were blown off, the lightning-rods detached, and much other damage done to the exterior of the building. Some alterations in the interior of the east wing have been made also.

The expenses attending "international exchanges" have steadily increased, until they now absorb about one-fourth of the entire income of the Institution. It has, therefore, in accordance with authority given by the Board of Regents, been decided to make a charge of five cents a pound on all packages received or sent by the government departments, a measure rendered necessary on account of the great increase in bulk of the public documents sent by them.

REPAYMENTS.

The Institution has made temporary advances during the year for freight, &c., the repayment of which, with the amount received from sales of the publications of the Institution, have been deducted from the expenditures for the year. These credits have been as follows:

Publications, sales	$261 83
Exchanges, repayments for freight	263 28
Books, repayment	30 00
Gallery of art, repayment	14 65
Postage, repayment	3 00
Incidentals, repayment	2 00
Total in 1878	$574 76

ESTIMATES.

The following are the estimates of receipts by the Institution for the year 1879, and the appropriations required for carrying on its operations during the same period:

Estimated receipts.

Interest on the permanent fund, receivable July 1, 1879, and January 1, 1880	$39,000 00
Interest on the Hamilton fund for 1879	60 00
Sale of Virginia coupons due January 1, 1879, and July 1, 1879	2,500 00
	41,560 00

Estimated appropriations.

For building	$2,000 00
For general expenses	14,000 00
For publications and researches	14,000 00
For exchanges	10,000 00
For books and apparatus	1,000 00
For contingencies	560 00
	41,560 00

The death of Professor Henry, the Secretary of the Institution, on the 13th of May, 1878, rendered necessary a special examination of the accounts up to that date by the Executive Committee, who found that, of the amount on hand at the beginning of the year 1878 ($25,083.90), there had been expended under his supervision and direction the sum of $16,560.92, every cent of which was accounted for by vouchers and entries in the usual books of account, with his characteristic precision and care. The balance ($8,522.98) was transferred, on the 28th of May, 1878, by the Treasurer of the United States, to the credit of the new Secretary of the Institution, Prof. Spencer F. Baird, in whose name the account of the Institution is now kept.

NATIONAL MUSEUM.

The following appropriations were made by Congress in 1878 for the "National Museum."*

"For preservation and care of the collections of the National Museum, including those from the International Exhibition of 1876," for the fiscal year ending June 30, 1879	$18,000 00
"For expenses of making up into sets, for distribution to institutions of learning and museums, the duplicate ores, minerals, and objects of natural history belonging to the United States," for the fiscal year ending June 30, 1879	5,000 00
	23,000 00
Armory Building.—"For expense of watching and storage of articles belonging to the United States, including those transferred from the International Exhibition of 1876," for the fiscal year ending June 30, 1879	2,500 00
	25,500 00

The following statement gives the receipts and expenditures of the National Museum during the year 1878:

RECEIPTS.

Balance of appropriation for "preservation of collections," January 1, 1878	$11,323 21	
Balance of appropriation for "Armory," January 1, 1878	1,488 25	
Balance of appropriation "National Museum" deficiency bill, January 1, 1878	2,040 90	
One half of the appropriation for "preservation of collections" and "distribution of duplicates," for year ending June 30, 1879	11,500 00	
One half of the appropriation for "Armory building," for year ending June 30, 1879	1,250 00	
Total receipts		$27,602 36

EXPENDITURES.

First quarter of 1878, January–March	Preservation	$6,338 55
	Armory	897 24
	Deficiency	1,914 18
Second quarter of 1878, April–June	Preservation	4,984 66
	Armory	591 01
	Deficiency	126 72

* Statutes of the United States, 1877–'78, page 233.

Third quarter of 1878, July–September	Preservation	$5,423 61	
	Armory	643 78	
Fourth quarter of 1878, October–December	Preservation	6,187 09	
	Armory	684 98	
Total expenditures			$27,781 82

The balance on hand for the purposes of the Museum for the remaining six months of the fiscal year ending 30th June, 1879, is $12,560.54; of which $11,389.30 belong to the "preservation" account, and $1,171.24 to the "Armory."

On the 27th of September, 1877, a commission was appointed by the President to examine the public buildings and report what additional means should be provided to secure them from destruction or injury by fire. This commission consisted of Col. Thomas L. Casey, United States Engineers, Commissioner of Public Buildings; Mr. Clark, Architect of the Capitol, and Mr. Hill, Architect of the Treasury. This Commission visited and inspected the Smithsonian Institution, and made the following report in regard to it, which was submitted to Congress on the 10th of December, 1877: *

"SMITHSONIAN INSTITUTION.—All the combustible materials used in the construction of the museum portion of the building should be removed and the parts renewed of fire-proof construction, and the openings connected with other parts of the building should be supplied with fire-proof doors."

An estimate has been submitted to Congress by the Hon. Secretary of the Interior for an appropriation of $3,000 to provide additional security against fire in the Smithsonian building for the government collections, in accordance with the foregoing report.

All payments on account of the "National Museum" are made by the disbursing-officer of the Department of the Interior on the presentation of the usual vouchers, approved by the Secretary of the Smithsonian Institution.

SUMMARY.

The Executive Committee have examined 755 vouchers for payments made from the Smithson income during the year 1878, and 578 vouchers for payments made from appropriations by Congress for the National Museum, making a total of 1,333 vouchers. All these vouchers bear the approval of the Secretary of the Institution, and a certificate that the materials and services charged were applied to the purposes of the Institution.

The committee have also examined the account books of the National Museum, and find the balance as before stated, viz, $12.560.54, to correspond with the certificates of the disbursing-officer of the Department of the Interior.

*Ex. Doc. No. 10, Forty-fifth Congress, Second session, House of Representatives.

The quarterly accounts-current, bank-book, check-book, and journal of the Institution have been examined and found to be correct, and show a balance to the credit of the Institution on the 8th of January, 1879, in the hands of the Treasurer of the United States, of $19,632.57, available for the current operations of the Institution.

Respectfully submitted.

PETER PARKER,
W. T. SHERMAN,
Executive Committee, Smithsonian Institution.

WASHINGTON, *January* 13, 1879.

JOURNAL OF PROCEEDINGS OF THE BOARD OF REGENTS.

WASHINGTON, D. C., *May* 13, 1878.

A meeting of the Board of Regents of the Smithsonian Institution was held this day at the Institution, at 8 o'clock p. m., under the following call:

SMITHSONIAN INSTITUTION,
May 13, 1878.

The Regents of the Smithsonian Institution are requested to meet at the Smithsonian building at 8 o'clock this Monday evening, to make suitable arrangements for the obsequies of Prof. Joseph Henry, whose decease occurred at 12.10 o'clock this afternoon.

By order of—

M. R. WAITE, *Chancellor.*

Present, the Chancellor—Chief Justice Waite, Hon. H. Hamlin, Hon. A. A. Sargent, Hon. R. E. Withers, Hon. H. Clymer, Hon. J. A. Garfield, Hon. Peter Parker, General W. T. Sherman.

The Chancellor made the following remarks:

MY BRETHREN OF THE BOARD OF REGENTS: I have asked you to come together this evening not to take action upon the great loss our Institution has sustained, but to consult as to what may best be done to pay honor to all that is mortal of the great and good man who, conceiving what Smithson willed, has devoted his life to making the bequest of our benefactor what he wished it to be, an instrument "for the increase and diffusion of knowledge among men."

The Chancellor stated that he understood that the family of Professor Henry had expressed the wish that the Board of Regents should make all the arrangements for the funeral.

Several of the Regents expressed their opinion that this was not the appropriate time to eulogize the deceased, as another and full meeting of the Board should be called for that purpose.

The following resolutions were adopted:

Resolved, That the Chancellor be directed to notify the President of the United States and his Cabinet, the Supreme Court of the United States, the Supreme Court of the District of Columbia, the two houses of Congress, the General of the Army, the Admiral of the Navy, the Diplomatic Corps, the Light-House Board, the National Academy of Sciences, the Washington Philosophical Society, and other organizations with which he was connected, of the death of Prof. Joseph Henry, and to invite them to attend his funeral.

Resolved, That the funeral take place on Thursday, 16th May, at the New York Avenue Presbyterian Church, at 4.30 o'clock p. m.

Resolved, That the Regents meet at the Institution on Thursday next at 4 o'clock p. m. to attend the funeral in a body.

Resolved, That a committee, consisting of General Sherman, Hon. Peter Parker, and Prof. S. F. Baird, Assistant Secretary of the Institution, be appointed to make arrangements for the funeral ceremonies.

Resolved, That a meeting of the Board of Regents be held on Friday next, 17th May, at 10 o'clock, a. m. for the purpose of transacting such business as may come before it.

The Board then adjourned.

WASHINGTON, D. C., *May* 17, 1878.

A meeting of the Board of Regents of the Smithsonian Institution was held this day at 10 o'clock a. m.

Present, the Chancellor—Chief Justice Waite, Hon. H. Hamlin, Hon. A. A. Sargent, Hon. R. E. Withers, Hon. H. Clymer, Hon. J. A. Garfield, Rev. Dr. John Maclean, Hon. Peter Parker, Dr. Asa Gray, General W. T. Sherman, President Noah Porter.

General Garfield was requested to act as secretary.

At the request of the Chancellor, Rev. Dr. Maclean led in prayer for Divine guidance of the Regents in their present deliberations.

The following resolutions were then adopted:

1. *Resolved*, That the Regents of the Smithsonian Institution hereby express their profound sorrow at the death of Prof. Joseph Henry, late Secretary of this Institution, and tender to the family of the deceased their sympathy for their great and irreparable loss.

2. *Resolved*, That in consideration of the long-continued, faithful, and unselfish services of Joseph Henry, our late Secretary, there be paid to his widow the same sum to which he would have been entitled, as salary, for the remainder of this year, and that the Secretary be directed to make payment to her for the amount thereof monthly.

3. *Resolved*, That Mrs. Henry be informed of this action of the Board, and the desire of the Regents that she will continue the occupancy of the apartments now in her use for such period, during the remainder of this year, as may suit her convenience.

4. *Resolved*, That a committee be appointed who shall prepare and submit to this Board at its next annual meeting a sketch of the life, character, and public services of the late lamented Secretary, which shall be entered upon the records.

5. *Resolved*, That the Executive Committee of the Board be requested to make arrangements for a public commemoration in honor of the late Secretary of the Institution, of such a character and at such a time as they may determine.

The Chancellor appointed as the special committee under the fourth resolution, President Porter, Dr. Gray, and Dr. Maclean.

On motion, it was resolved to consider the subject of election to fill the vacancy in the office of Secretary of the Institution.

Dr. Parker urged the propriety of deferring the election of Secretary to a later meeting, as it might appear precipitate to elect now.

Senator Hamlin thought the Board ought to proceed at once to elect a Secretary. To delay would be to invite great contention for the office.

Senator Withers thought the discussion should be confined to the question of postponement.

Dr. Parker then moved that the appointment of a permanent Secretary be postponed until the next annual meeting in January, and suggested that the Assistant Secretary might be invested with power to perform all the functions of Secretary during the *interim.*

Dr. Maclean said that when President Burr, of Princeton, died, his successor, President Edwards, was elected the fourth day after. He thought prompt action the wisest, and advocated the election of Professor Baird.

Mr. Clymer read the statute, and insisted that the Board was legally bound to elect a Secretary. No funds could be drawn nor payments made by any other officer, and an *ad interim* appointment was not provided for by the law of organization.

General Garfield suggested to Dr. Parker that he withdraw his motion, and that the Board proceed to elect, so that action might be taken of an affirmative rather than of a negative character.

President Porter expressed the opinion that the Board could elect a Secretary *pro tempore.*

Dr. Parker then withdrew his motion; and the construction of the statute by Mr. Clymer was agreed to by the majority of the Board.

Mr. Clymer moved to proceed to the election of a Secretary; which was agreed to.

The Chancellor appointed Mr. Sargent and Mr. Clymer as tellers.

The vote was then taken by ballot, and the tellers reported that eleven ballots were cast, all of which were for Spencer Fullerton Baird.

Messrs. Sargent and Clymer were appointed a committee to wait upon Professor Baird and inform him of his election, and invite him to attend the meeting of the Board.

The committee discharged this duty; and at half past eleven o'clock a. m. introduced the Secretary-elect to the Regents.

The Chancellor then formally announced to Professor Baird his unanimous election as Secretary.

Professor Baird made a brief acknowledgment of the honor conferred upon him, and stated that he would endeavor to discharge his duties faithfully and in accordance with the views of his lamented predecessor.

On motion, it was

Resolved, That the Chancellor prepare a suitable notice of the death of Professor Henry, to be sent to foreign establishments in correspondence with the Institution, and also notifying them of the election of Professor Baird as Secretary.

The Chancellor stated that the resignation of Mr. Bancroft had occasioned a vacancy in the Executive Committee, and, on motion, it was

Resolved, That the vacancy in the Executive Committee be filled by the election of General Sherman.

The Board then adjourned *sine die.*

Agreeably to the resolution of the Board, the Chancellor of the Institution, on behalf of the Regents, prepared the following circulars, which were promptly distributed to the correspondents of the Institution in all parts of the world:

"SMITHSONIAN INSTITUTION,
"*Washington, D. C., May* 14, 1878.

"On behalf of the Regents of the Smithsonian Institution, it becomes my mournful duty to announce the death of the Secretary and Director of the Institution, Joseph Henry, LL. D., which occurred in this city on Monday, May 13, at 12.10 o'clock p. m.

"Professor Henry was born in Albany, in the State of New York, December 17, 1799. He became professor of mathematics in the Albany Academy in 1826; professor of natural philosophy in the College of New Jersey, at Princeton, in 1832, and was elected the first Secretary and Director of the Smithsonian Institution in 1846.

"He received the honorary degree of Doctor of Laws from Union College in 1829, and from Harvard University in 1851.

"He was president of the American Association for the Advancement of Science in 1849; was chosen president of the United States National Academy of Sciences in 1868; president of the Philosophical Society of Washington in 1871, and Chairman of the Light-House Board of the United States in the same year; the last three positions he continued to fill until his death.

"Professor Henry made contributions to science in electricity, electromagnetism; meteorology, capillarity, acoustics, and in other branches of physics; he published valuable memoirs in the transactions of various learned societies of which he was a member, and devoted thirty-two years of his life to making the Smithsonian Institution what its founder intended it to be, an efficient instrument for the "increase and diffusion of knowledge among men."

"M. R. WAITE,
"*Chancellor of the Smithsonian Institution.*

"SMITHSONIAN INSTITUTION,
"*Washington, D. C., May* 17, 1878.

"At a special meeting of the Board of Regents of the Smithsonian Institution, held this day, Prof. Spencer Fullerton Baird, for many years the assistant secretary of the Institution, was duly elected as the Secretary of the Smithsonian Institution, to succeed the late Prof. Joseph Henry.

"M. R. WAITE,
"*Chancellor of the Smithsonian Institution.*"

WASHINGTON, D. C., *January* 15, 1879.

A meeting of the Board of Regents of the Smithsonian Institution was held this day in the Regents' room, at 10 o'clock a. m.

Present, the Chancellor—Chief Justice Waite; Hon. W. A. Wheeler, Vice-President of the United States, Hon. A. A. Sargent, Hon. R. E. Withers, Hon. J. A. Garfield, Hon. H. Clymer, Dr. J. Maclean, Dr. A. Gray, Dr. H. Coppée, Hon. Peter Parker, President Porter, General Sherman, and the Secretary, Professor Baird.

An excuse was received from Hon. H. Hamlin for non-attendance, his absence being occasioned by his appointment by the Senate on a special committee to accompany the remains to Texas of Hon. G. Schleicher, a deceased member of Congress.

The minutes of the last meeting were read and approved.

The following communication from Mrs. Henry was laid before the Board by the Chancellor:

Hon. M. R. WAITE,
Chief Justice of the United States,
Chancellor of the Smithsonian Institution:

MY DEAR SIR: In my great affliction it is consoling to receive from friends tributes of sympathy and testimonials of respect for my late husband. I feel very deeply the kind consideration of the Board of Regents in their official capacity. Permit me, through you, to express to them the heartfelt thanks of my children and myself for the liberality extended to us and the full appreciation of Mr. Henry's character and labors while connected with the Institution, and for the public testimonials of respect and honor to his memory.

With my best wishes for the continued prosperity of the Institution, believe me yours, respectfully,

H. A. HENRY.

WASHINGTON, *January* 15, 1879.

On motion of General Garfield, it was—

Resolved, That the letter of Mrs. Henry be placed in the files of the Institution, and entered in the journal of the Board.

The Secretary, Professor Baird, presented a statement of the financial condition of the Institution for the year 1878, which for convenience of reference he had printed.

Dr. Parker, in behalf of the Executive Committee, presented the annual report of receipts, expenditures, estimates, &c., which at his request was read by General Sherman.

On motion of Mr. Withers, the report was adopted.

Dr. Parker, in behalf of the Executive Committee, presented a report in relation to the duty imposed on them by the fifth resolution of the Board of Regents, adopted at the meeting of May 17, 1878, "to make arrangements for a public commemoration in honor of the late Secretary of the Institution." The committee had held numerous meetings, the minutes of which were read, and the arrangements had finally been made as follows:

The exercises will be held in the Hall of the House of Representatives on Thursday evening, 16th of January, 1879.

The Vice-President of the United States, supported by the Speaker of the House, will preside on this occasion, and the Senate and House will take part in the exercises.

1. Opening prayer by Rev. Dr. McCosh, President of Princeton College.
2. Address by Hon. H. Hamlin, of the United States Senate.
3. Address by Hon. R. E. Withers, of the United States Senate.
4. Address by Prof. Asa Gray, of Harvard University.
5. Address by Prof. W. B. Rogers, of Boston.
6. Address by Hon. Jas. A. Garfield, of the House of Representatives.
7. Address by Hon. S. S. Cox, of the House of Representatives.
8. Address by General W. T. Sherman.
9. Concluding prayer by Rev. Dr. Sunderland, Chaplain of the Senate.

By authority of the Speaker of the House, reserved seats will be provided on the floor of the House for the following bodies with which Professor Henry was associated:

1. The Regents of the Smithsonian Institution and the orators of the evening, who will meet in the room of the Speaker of the House.
2. The National Academy of Sciences.
3. The Washington Philosophical Society.
4. The Light-House Board, who will meet in the room of the Committee of Ways and Means.
5. The Alumni Association of Princeton College.
6. The Trustees of the Corcoran Gallery of Art.
7. The Washington Monument Association, who will meet in the room of the Committee on Appropriations.

On motion of Mr. Sargent, the action of the committee was approved.

On motion of General Garfield, it was—

Resolved, That the Board of Regents assemble on Thursday evening next at half past seven o'clock, in the Speaker's room at the Capitol, to proceed in a body to attend the exercises in the Hall of the House of Representatives in honor of the memory of Professor Henry.

On motion of General Garfield, it was—

Resolved, That the Chancellor be empowered to act for the Board of Regents in making the final arrangements for the memorial exercises.

President Porter, from the special committee appointed at the last meeting, under the fourth resolution adopted by the Board, "to prepare a sketch of the life, character, and public services of Professor Henry," made a report that Dr. Gray had been selected by the committee to prepare the eulogy on behalf of the Board of Regents, and that it would form part of the exercises at the public commemoration at the Capitol.

Dr. Gray remarked that he had only recently been informed of his appointment to perform the service required, but that he had prepared a paper, which he would now present to the Board.* He had been limited by the committee to thirty minutes, but had arranged with Professor Rogers so that both should only occupy an hour. He would, however, insert details and documents in notes which could be printed with the eulogy.

On motion of General Garfield, Dr. Gray was requested, as the representative of the Board of Regents, to make his address as full and complete as possible.

General Garfield called attention to the fact that the increased business of the Institution had made it necessary to take the rooms in the east wing, formerly occupied by Professor Henry as a residence, for offices, and that it was therefore proper that a suitable allowance be made to Professor Baird for house-rent. After some conversation on the subject, it was—

Resolved, That the Executive Committee consider the propriety of making an allowance to the Secretary for house-rent and report on the subject at the next meeting of the Board.

On motion of Dr. Gray, it was—

Resolved, That the Board adjourn to meet on Friday morning, 17th January, at half-past 9 o'clock, to hear the annual report of the Secretary and to transact any other business which may be necessary.

The Board then adjourned.

WASHINGTON, D. C., *January* 16, 1879.

A meeting of the Board of Regents was held this day at 7.30 o'clock, p. m., in the room of the Speaker of the House of Representatives, and at 8 o'clock the Regents proceeded in a body to the Hall of the House of Representatives, to attend the public exercises in honor of Prof. Joseph Henry, late Secretary of the Smithsonian Institution.

WASHINGTON, D. C., *January* 17, 1879.

A meeting of the Board of Regents was held this day in the Regent's room at 9.30 o'clock a. m.

Present, the Chancellor—Chief-Justice Waite, Hon. A. A. Sargent, Hon. R. E. Withers, Hon. James A. Garfield, Hon. Hiester Clymer,

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*See Appendix to Journal of the Board.

Hon. Peter Parker, Rev. Dr. John Maclean, Prof. Asa Gray, Prof. Henry Coppée, President Noah Porter, General Sherman, and the Secretary, Professor Baird.

The minutes of the meeting of January 15 were read and approved.

The Chancellor laid before the Board several hundred letters received in reply to the circulars issued by the Institution, announcing the death of Professor Henry, and the election of his successor.

The subject of the publication of the eulogies on Professor Henry, together with an account of his scientific writings, &c., was discussed, and on motion of Dr. Maclean, it was—

Resolved, That a special committee of three be appointed, of which the Secretary of the Institution shall be one, to prepare a memorial of Professor Henry, to include in a separate volume of the Smithsonian series such biographies and notices of the late Secretary of the Institution as may be considered by them worthy of preservation and publication.

The Chancellor appointed Messrs. Gray, Parker, and Baird, as the committee.

The Chancellor then stated that any remarks the Regents desired to make in relation to Professor Henry were in order.

Dr. Parker addressed the Board as follows:

MR. CHANCELLOR AND FELLOW REGENTS: We are making history, and I wish to say a few words that shall remain upon its page, in memory of Joseph Henry, our beloved and lamented friend and Secretary, when we, like him, shall have passed from earth.

Many have already pronounced his eulogy and set forth his rare talents and influence upon the world, and I need not, and could not, were I to attempt it, add to your appreciation of Professor Henry, his life and character, as a friend, scientist, and Christian, the highest type of man.

For twenty years I have been intimately acquainted with Professor Henry, and happily associated with him in many ways; for ten years as a Regent of the Smithsonian Institution, and as a member of the Executive Committee all that period our intercourse has been frequent and intimate. *I have never known a more excellent man.*

His memory has been much on my mind since he left us, and I often find myself inquiring how he and others like him are occupied now. His connection with time is severed, but his existence continues. When I recall the names of Professors Franklin Bache, Charles G. Page, Louis Agassiz, *Joseph Henry*, and others of similar intellect and virtue, I find myself asking the question, Are to them all consciousness and thought suspended by separation from the body? I am reluctant to come to such conclusion. But this I know, *the Infinite Father's ways are right.*

It seems most providential that Professor Henry had the opportunity and the strength to give in person his last words, a priceless legacy, to the National Academy at its annual meeting in Washington, in April, and through that association to the civilized and scientific world; I refer to his sentiment "*that moral excellence is the highest dignity of man.*"

The loftiest talents and highest attainments without this are deficient in that, which, in the judgment of wise men and of Infinite Wisdom, is of greatest worth. Was there ever a man from whom the sentiment could come with better grace?

The opinion has been expressed, and I do not regard it extravagant, that the letter addressed by Professor Henry to his friend Joseph Patterson, emanating from such a mind, *such a man*, at the close of a protracted life of singular distinction, was worth a lifetime to produce. It has probably been read by millions, in various languages, and will be by future generations.

Professor Henry was not only a man of science, a discoverer of nature's laws and forces, but a sincere believer in God their Author and in his atoning Son. To quote his language: "We are conscious of having evil thoughts and tendencies that we cannot associate ourselves with a Divine Being, who is the Director and Governor of all, or even call upon him for mercy, without the intercession of one who may affiliate himself with us."

Let me quote from the prayer offered at his obsequies and to which we repeat our sincere *Amen;* the lips that uttered it, in less than one short month were silent in death, and the two remarkable men, Professors Joseph Henry and Charles Hodge, closely united in life were not long divided by death:

"We thank Thee, O God, that Joseph Henry was born; that Thou didst endow him with such rare gifts, intellectual, moral, and spiritual; that Thou didst spare him to a good old age, and enable him to accomplish so much for the increase of human knowledge and for the good of his fellow-men; and above all that Thou didst hold him up before this whole nation as such a conspicuous illustration of the truth that moral excellence is the highest dignity of man."

On motion of Dr. Maclean, it was—

Resolved, That the thanks of the Board of Regents be presented to the gentlemen who took part in the memorial services held in the United States Capitol on the 16th of January in honor of the late Professor Henry, and that they be requested to furnish copies of their remarks on that occasion.

Dr. Maclean stated that he intended in the above resolution to include General Sherman, who was prevented by the lateness of the hour from delivering the whole address he had prepared, Rev. Drs. McCosh and Sunderland, who offered prayers, and Mr. Clymer, who made a few introductory remarks of an exceedingly interesting character in presenting telegrams which had been sent to the meeting from London.

General Sherman, from the Executive Committee, presented a report on the subject of an allowance for house-rent to the Secretary, with the following preamble and resolution:

Whereas the east wing of the Smithsonian building, heretofore used as a residence by Professor Henry, is required for the purposes of the Institution; and whereas the present Secretary owns and occupies a separate residence in the city of Washington, for which it is but just and proper that he should be allowed compensation: Therefore,

Resolved, That the Secretary of the Smithsonian Institution, Prof. S. F. Baird, be allowed the sum of one hundred dollars per month for rent, fuel, gas, &c., from the date of his election as Secretary, May 17, 1878, to the 31st of December, 1879.

The Secretary presented his annual report, which was read, and it was

Resolved, That the annual report of the Secretary be approved and transmitted to Congress.

Dr. Parker suggested that there was a matter of some importance which ought to receive attention at this meeting. The Senate had passed on the 9th of January the following bill

For the erection of a fire-proof building for the National Museum.

"*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled*, That for a fire proof building for the use of a National Museum, three hundred feet square, to be erected under the direction and supervision of the Regents of the Smithsonian Institution, in accordance with the plans now on file with the Joint Committee of Public Buildings and Grounds, on the southeast corner of the grounds of the Smithsonian Institution, the sum of two hundred and fifty thousand dollars is hereby appropriated out of any money in the Treasury not otherwise appropriated; said building to be placed east of the Smithsonian Institution, leaving a roadway between it and the latter of not less than fifty feet, with its north front on a line with the south face of the buildings of the Agricultural Department and of the Smithsonian Institution; and all expenditures for the purposes herein mentioned, not including anything for architectural plans, shall be audited by the proper officers of the Treasury Department."

If this should pass the House and become a law it would be necessary for the Board of Regents to take action in regard to the new building.

On motion of Mr. Clymer, it was

Resolved, That the Executive Committee of this Board, and the Secretary, or a majority thereof, be, and they are hereby, authorized and empowered to act for and in the name of the Board of Regents in carrying into effect the provisions of any act of Congress which may be passed providing for the erection of a building for the National Museum.

The Board then adjourned *sine die.*

BIOGRAPHICAL MEMOIR OF JOSEPH HENRY,

PREPARED IN BEHALF OF THE BOARD OF REGENTS,

BY

PROF. ASA GRAY.

The Regents of the Smithsonian Institution, on the day following the obsequies of their late Secretary, resolved to place upon record, by the hands of their committee, a memorial of their lamented associate. The time has arrived when this should be done, now that the Institution enters upon another official year, and its bereavement is brought freshly to mind.

Although time may have assuaged our sorrow, as time will do, and although the recollection that a well-spent life was well appreciated and not prematurely closed should temper regret, yet they have not dulled our sense of loss, nor lessened our estimate of the signal services to science, to this Institution, and to the general good which remarkable gifts and a devoted spirit enabled this man to render.

If we would fit this memorial to the subject of it, we must keep in mind Professor HENRY'S complete and transparent, but dignified simplicity and modesty of character, in which a delicate sense of justice went along with extreme dislike of exaggeration, and aversion to all that savored of laudation.

Yet it is not for ourselves, his associates—some of few, some of many years—that this record is made; nor need we speak for that larger circle of his associates, the men of science in our land, who will, in their several organizations, recount the scientific achievements of their late leader and Nestor. And nothing that we can say will enhance the sentiments of respect, veneration, and trust with which he was regarded here, in Washington, by all who knew him, whether of high or humble station. Even those, here or elsewhere, who came only into occasional intercourse with him, will remember that thoughtful and benignant face;—certainly it will be remembered by those who, in that recourse to him which it was always easy to gain, have seen the mild seriousness of a somewhat abstracted and grave mien change into a winning smile, sure precursor of pleasant words, cheerful attention, and, if need were, wise counsel and cordial help. But we are all passing, as he has passed, and the tribute to his memory which it is our privilege to pay, is a duty to those who are to come after us.

JOSEPH HENRY was of Scotch descent. His grandparents, paternal and maternal, landed at New York from the same vessel on the day before the battle of Bunker Hill. The Henrys settled in Delaware County, the Alexanders in Saratoga County, New York. Of his father, William Henry, little is known. He died when his oldest son, Joseph, was eight or nine years old. His mother lived to a good age.* He was born at Albany very near the close of the last century.† His boyhood was mostly passed with his maternal grandmother in the country at Galway. His early education was such as a country common school would furnish to a lad of inquisitive mind but no aptness for study. The fondness for reading came early, but in a surreptitious way.

One day, in the pursuit of a pet rabbit, he penetrated through an opening in the foundation-wall of the village meeting-house. A glimmer of light enticed him through the broken floor into a room above, in which an open bookcase contained the village library. He took down a book—Brooks's Fool of Quality—was soon absorbed in the perusal, returned again and again to this, which he said was the first book he ever opened voluntarily, and to all the works of fiction which the library contained. Access in the regular way was soon granted to him.

The lad at this time was a clerk, or office-boy, in the store of a Mr. Broderick. He returned to Albany at the age of fourteen or fifteen. We may count it as a part of his education that he there served a brief apprenticeship to a silversmith, in which he acquired the manual dexterity afterward so useful to him. Opportunely perhaps, the silversmith soon failed in business, and young HENRY was thrown out of employment. His powers were now developing, but not in the line they were soon to take. To romance reading was now joined a fondness for the theater. Not content with seeing all the plays he could, he found his way behind the scenes, and learned the methods of producing stage

* She is remembered as a lady of winning refinement of mien and character, of small size, with delicate Grecian features, fair complexion, and when young she is said to have been very beautiful.

† The date, December 17, 1797, given in the American Cyclopedias, appears to be wrong; was perhaps misprinted. There is little doubt that he was born on the 17th of December, 1799.

effects. He joined a juvenile forensic and theatrical society, called the Rostrum, and soon distinguished himself in it by his ingenuity in stage arrangements. He was made president, and having nothing else to do at the time, he gave his whole attention to the Rostrum. He dramatized a tale, wrote a comedy, and took a part in its representation. Unusually comely in form and features, and of prepossessing address, our future philosopher was in a fair way to become an actor, perhaps a distinguished one.

But now a slight illness confined him for a few days to his mother's house. To while away the hours he took up a small book which a Scotchman, who then occupied a room in the house, had left upon his mother's table. It was "Lectures on Experimental Philosophy, Astronomy, and Chemistry, intended chiefly for the use of young persons, by G. Gregory," an English clergyman. It is an unpretending volume, but a sensible one. It begins by asking three or four questions, such as these:

"You throw a stone, or shoot an arrow into the air; why does it not go forward in the line or direction that you give it? Why does it stop at a certain distance, and then return to you? * * * On the contrary, why does flame or smoke always mount upward, though no force is used to send them in that direction? And why should not the flame of a candle drop toward the floor when you reverse it, or hold it downward, instead of turning up and ascending into the air? * * * Again, you look into a clear well of water and see your own face and figure, as if painted there. Why is this? You are told that it is done by reflection of light. But what is reflection of light?"

Young HENRY'S mind was aroused by these apt questions, and allured by the explanations; he now took in a sense of what knowledge was. The door to knowledge opened to him, that door which it thence became the passion of his life to open wider. Thenceforth truth charmed him more than fiction. At the next meeting of his dramatic association he resigned the office of president and took his leave in a valedictory address, in which he assured his comrades that he should now prepare to play his part on another stage, with nobler and more impressive scenes. The volume itself is preserved in Professor HENRY'S library. On a fly-leaf is the following entry:

"This book, although by no means a profound work, has, under Providence, exerted a remarkable influence upon my life. It accidentally fell into my hands when I was about sixteen years old, and was the first work I ever read with attention. It opened to me a new world of thought and enjoyment; invested things before almost unnoticed with the highest interest; fixed my mind on the study of nature, and caused me to resolve at the time of reading it that I would immediately commence to devote my life to the acquisition of knowledge."

The pursuit of elementary knowledge under difficulties and privations now commenced. At first he attended a night-school, where he soon learned all the master could teach. At length he entered Albany Academy, earning the means at one time by teaching a country district school, later by serving as tutor to the sons of Gen. Stephen Van Rensselaer the patroon. Then he took the direction of a road-survey across the southern portion of the State, from West Point to Lake Erie, earning a little money and much credit. He returned to Albany Academy as an assistant teacher, but was very soon, in 1828, appointed professor of mathematics. He had already chosen his field, and began to make physical investigations.

It is worth noticing that just when HENRY'S youthful resolution to devote his life to the acquisition of knowledge was ready to bear fruit, another resolve was made, in England, by another scientific investigator, James Smithson, in his will, executed in October, 1828, wherein he devoted his patrimony "TO FOUND AT WASHINGTON AN ESTABLISHMENT FOR THE INCREASE AND DIFFUSION OF KNOWLEDGE AMONG MEN." Who could have thought that the poor lad, who resolved to seek for knowledge as for hid treasure, and the rich man of noble lineage, who resolved that his treasure should increase and diffuse knowledge, would ever stand in this interesting relation; that the one would direct and shape the establishment which the other willed to be founded!

The young professor's position was an honorable but most laborious one. Although Albany Academy was said by the distinguished president of Union College in those days to be "a college in disguise," it began its work low down. Its new professor of mathematics had to teach seven hours of every day, and for half of this time to drudge with a large class of boys in the elements of arithmetic. But he somehow found time to carry on systematically the electro-magnetic researches which he had already begun. In the very year of his appointment, 1828, he described in the Transactions of the Albany Institute a new application of the galvanic multiplier, and throughout that year and the next he carried on those investigations which, when published at the beginning of the ensuing year, January, 1831, in that notable first paper in the American Journal of Science and the Arts, at once brought HENRY'S name to the front line among the discoverers in electro-magnetism.

Sturgeon may be said to have first made an electro-magnet; HENRY undoubtedly made the electro-magnet what it is. Just after Barlow in England had declared that there could be no electric telegraph to a long distance, HENRY discovered that there could be, how and why it could be; he declared publicly its practicability, and illustrated it experimentally by setting up a telegraph with such length of wire as he could conveniently command, delivering signals at a distance by the sounding of a bell.

Previously to his investigations the means of developing magnetism in soft iron were imperfectly understood (even though the law from which they are now seen to flow had been mathematically worked out by Ohm), and the electro-magnet which then existed was inapplicable to the transmission of power to a distance. HENRY first rendered it applicable to the transmission of mechanical power to a distance; was the first actually to magnetize a piece of iron at a distance, and by it to deliver telegraphic signals. He showed what kind of battery must be employed to project the current through a great length of wire, and what kind of coil should surround the magnet used to receive this current and to do the work.*

For the telegraph, and for electro-magnetic machines, what was now wanted was not discovery, but invention, not the ascertainment of principles, but the devising of methods. These, the proper subjects of patent, have been supplied in various ways and, as to the telegraph, with wonderful efficiency;—in Europe, by the transmission of signs through the motion of a magnetic needle; in America, by the production of sounds or records by the electro-magnet. Morse was among the first to undertake the enterprise, and—when directed to the right way through Professor Gale's acquaintance with HENRY'S published researches—he carried the latter mode into practical and most successful execution. If HENRY had patented his discovery, which he was urged, but declined to do, Morse could have patented only his alphabetical mode of signaling, and perhaps the use of relay-batteries, the latter indispensable for long lines upcn that system.

The scientific as well as popular effect of Professor HENRY'S first paper in Silliman's Journal was immediate and great. With the same battery that Sturgeon used he developed at least a hundred times more magnetism. The instantaneous production of magnets lifting four hun-

*See Supplementary Note I, Leading Points in the History of the Telegraph.

dred and twenty times their own weight, of those which with less than a pint of dilute acid acting on two hands' breadth of zinc would lift seven hundred and fifty pounds, and this afterward carried up to a magnet lifting thirty-three hundred pounds, was simply astonishing. Yet it was not these extraordinary results, nor their mechanical applications, which engaged Professor HENRY'S attention so much as the prospect they opened of a way by which to ascend to higher discovery of the laws of nature. In other hands, his discoveries furnished the means by which diamagnetism, magnetic effects on polarized light, and magneto-electricity—now playing so conspicuous a part—soon came to be known. In his own hands, the immediate discovery of the induction of a current in a long wire on itself* led the way to his next fertile field of inquiry, the following up of which caused unwise tardiness in the announcement of what he had already done. For it is within our knowledge that the publication of the paper which initiated his fame had been urged for months by scientific friends, and at length was hastened by the announcement of some partly similar results reached in a different way by Moll, of Utrecht. In a letter not long afterward written to one of us, Professor HENRY had occasion to declare: "My whole ambition is to establish for myself *and to deserve* the reputation of a man of science." Yet throughout his life ardor for discovery and pure love of knowledge were unattended by corresponding eagerness for publication. At the close of that very year, 1832, however, he did announce the drawing of a spark from a magnet, that first fact in magneto-electricity, and, as he supposed, a new one. But he had been anticipated.

In May, 1830, Professor HENRY married his cousin, Harriet L. Alexander, of Schenectady, who, with three daughters, survives. Two earlier children died in infancy, and a son in early manhood.

Pleasant in most respects as his situation at Albany was, it was not an unwelcome invitation which, in the summer of 1832, it became the duty and the privilege of the most venerable of our number, then vice-president of the College of New Jersey, to give to Professor HENRY, offering him the chair of Natural Philosophy at Princeton. By this early call that college secured him for her own during the years most prolific for science. It was on a later occasion that Sir David Brewster wrote: "The mantle of Franklin has fallen upon the shoulders of HENRY." But the aureole was already visible to his fellow-workers in science;

* Announced in American Journal of Science and the Arts in 1832.

and Silliman, Renwick, and Torrey urged his acceptance of the new position, and congratulated Princeton upon the acquisition.

The professorship came to him unsought. In his last address to one of the learned societies over which he presided, Professor HENRY mentions that the various offices of honor and responsibility which he then held, nine in number, had all been pressed upon him; that he never occupied a position for which he had of his own will and action been made a candidate. It did not occur to him at that moment to make one exception. When a pupil in Albany Academy he once offered himself as a teacher of a country district school. The school trustees thought him too young, but took him on trial at eight dollars a month. At the beginning of the second month they raised his pay to fifteen.

At Princeton Professor HENRY found congenial companions and duties well suited to his powers. Here he taught and investigated for fourteen fruitful and happy years; here he professed the faith that was in him, entering into the communion of the Presbyterian Church, in which he and his ancestors were nurtured; and here he developed what might not have been expected—a genius for education. One could count on his being a clear expositor, and his gifts for experimental illustration and for devising apparatus had been already shown. But now, as a college professor, the question how to educate came before him in in a broader way. He appreciated, and he made his associates and pupils appreciate, the excellence of natural philosophy for mental discipline, for training at once both the observing and the reasoning faculties. A science which rises from the observation of the most familiar facts, and the questioning of these by experiment, to the consideration of causes, the ascertaining of laws, and to the most recondite conceptions respecting the constitution of matter and the interplay of forces, offers discipline to all the intellectual powers, and tasks the highest of them. Professor HENRY taught not only the elementary facts and general principles from a fresh survey of both, but also the methods of philosophical investigation, and the steps by which the widest generalizations and the seemingly intangible conceptions of the higher physics have been securely reached. He exercised his pupils in deducing particular results from admitted laws, and in then ascertaining whether what was thus deduced actually occurred in nature; and if not, why not. Though very few of a college class might ever afterward undertake a physical or chemical investigation, all would or should be concerned in the acquisition of truth and its relations; and by knowing how truth was won and knowledge advanced in one field of inquiry, they would gain the aptitude which any real investigation may give, and the confidence that springs from a clear view and a sure grasp of any one subject.

He understood, as few do, the importance of analogy and hypothesis in science. Premising that hypothesis should always be founded on real analogies and used interrogatively, he commended it as the prerequisite to experiment, and the instrument by which, in the hands of sound philosophers, most discoveries have been made. This free use of hypothesis as the servant and *avant-courier* of research—as means rather than end—is a characteristic of HENRY. His ideas on the subject are somewhat fully and characteristically expounded by himself in his last presidential address to the Philosophical Society of Washington—one which he evidently felt would be the last.

How HENRY was valued, honored, revered at Princeton, the memorial published by his former associates there feelingly declares. What he did there for science in those fourteen years would be long to tell and difficult to make clear without entering into details, here out of place. Happily the work has been done to our hand by the Professor himself, several years ago, in a communication which is printed in the index volume of the Princeton Review, and reprinted in the Princeton Memorial. This careful and conscientious, though cursory, analysis of the principal researches of that period we propose to append to this record.* There is also in preparation, by a competent scientific hand, a detailed list of all Professor HENRY'S contributions to science, which we desire likewise to append.†

One of these, of the Princeton period, ought to be mentioned. It is upon the origin of mechanical power and its relations to vital force. It is a characteristic example of Professor HENRY'S happy mode of treating a scientific topic in an untechnical way. It also illustrates his habit of simply announcing original ideas without putting them prominently forward in publication, as any one who was thinking of himself and of his own fame would be sure to do. The doctrine he announced was communicated to the American Philosophical Society in 1844 in brief outlines. He developed it further in an article published in the Patent Office Report for 1856, twelve years later; a medium of publication which was naturally overlooked. Only at a friend's desire was the paper re-

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* See Supplementary Note II. A Letter from Professor Henry.

† See Supplementary Note III. A List of Professor Henry's Scientific Papers.

produced, in 1860, in the American Journal of Science, where it would be noticed. The attention of Professor HENRY was turned to the topic (as we happen to know) by an abstract which was given to him of Dumas' celebrated lecture, in 1841, on the Chemical Statics of Organized Beings. If he had published in 1844, with some fullness, as he then wrought them out, his conception and his attractive illustrations of the sources, transformation, and equivalence of mechanical power, and given them fitting publicity, HENRY'S name would have been prominent among the pioneers and founders of the modern doctrine of the conservation of energy.

In the year 1837 Professor HENRY first visited Europe, and came into personal communication with the principal men of science of England, Scotland, and France. One of us had the pleasure, a few years afterward, of hearing Faraday speak of HENRY in terms of hearty regard and admiration. The two men were in some respects alike, wholly alike in genuine simplicity of character and in disinterested devotion to scientific discovery. They were then rival investigators in the same line; and the race for a time was not unequal, considering how HENRY was weighted with onerous professional work. For Faraday, while that most acute mind retained its powers, there was the congenial life of pure research, undistracted by cares of administration or of instruction, beyond a few popular lectures; supplied with every means of investigation; stimulated by the presence or proximity of many fellow-workers; rewarded by discovery after discovery, and not unconscious of the world's applause—such was the enviable life of the natural philosopher favorably placed. But in this country, where fit laborers are few, duty rather than inclination must determine their work. Midway in his course Professor HENRY was called to exchange a position which allowed the giving of considerable time to original researches, for one of greater prominence, in which these had practically to be abandoned. Not, indeed, that this was assuredly expected, but it was contemplated as probable. And the event justified the apprehension, while it opened other fields of not inferior usefulness.

In August, 1846, the act of Congress establishing the Smithsonian Institution was passed and approved. On the 7th of September ensuing the Regents held their first meeting. On the 3d of December following they resolved:

"That it is essential for the advancement of the proper interests of the trust that the Secretary of the Smithsonian Institution be a man possessing weight of character and a high grade of talent; and that it is further desirable that he possess eminent scientific and general acquirements; that he be a man capable of advancing science and promoting letters by original research and effort, well qualified to act as a respected channel of communication between the Institution and scientific and literary individuals and societies in this and foreign countries; and, in a word, a man worthy to represent before the world of science and letters the Institution over which this Board presides."

Immediately following the adoption of this resolution, Professor JOSEPH HENRY, of Princeton, was elected Secretary. On the 14th of December a letter was read from him accepting the appointment. At the meeting a week later, he appeared and entered upon the duties of his office. From this time the biography of Professor HENRY is the history of the Institution. That history is set forth in the Secretary's annual reports, presented by the Board of Regents to Congress, and it need not be recapitulated. A few words may give some idea of the deep impression he made upon the Institution while it was yet plastic.

Some time before his appointment he had been requested by members of the Board of Regents to examine the will of Smithson, and to suggest a plan of organization by which the object of the bequest might, in his opinion, best be realized. He did so, and the plan he drew was in their hands when he was chosen Secretary. As he himself summed it up, the plan was based on the conviction "that the intention of the donor was to advance science by original research and publication; that the establishment was for the benefit of mankind generally, and that all unnecessary expenditures on local objects would be violations of the trust." The plan proposed was, in the leading feature, "to assist men of science in making original researches, to publish them in a series of volumes, and to give a copy of these to every first-class library on the face of the earth."

His "Plan of Organization," filled out in its details and adjusted to the conditions prescribed by the law and by the action of the Regents, was submitted to the Board in the following year, was adopted as its "governing policy," and it has been reprinted, in full or in part, in almost every annual report. All would understand, therefore, that Professor HENRY'S views were approved, and that they would be carried into effect as far and as fast as they commended themselves to the judgment of the Regents, and as opportunity made them practicable.

If the Institution is now known and praised throughout the world of science and letters, if it is fulfilling the will of its founder and the reasonable expectations of the nation which accepted and established the trust, the credit is mainly due to the practical wisdom, the catholic spirit, and the indomitable perseverance of its first Secretary, to whom the establishing act gave much power of shaping ends which, as rough-hewn by Congress, were susceptible of various diversion. For Congress, in launching, did not shape the course of the Institution, except in a general way. And in intrusting its guidance to the Regents, the law created only one salaried and permanent officer, the Secretary, on whom, by its terms and by the conditions of the case, it devolved great responsibility and commensurate influence. Some of us are old enough to remember the extreme diversity of opinion in Congress over the use to be made of Smithson's legacy. One party, headed by an eminent statesman and Ex-President, endeavored to found with it an astronomical observatory, for which surely the country need not be indebted to a foreigner. A larger party strove to secure it for a library; not, probably because they deemed that use most relevant to the founder's intention, but because rival schemes might fritter away the noble bequest in popular lecturing, itinerant or stationary, of which the supply and the quality are in this country equal to the demand; or in the dissemination of elementary knowledge by the printing-press, as if that were beyond the reach of private enterprise; or in setting up one more college, university, or other educational establishment on half an endowment; or in duplicating museums and cabinets, which, when supported by a fixed capital, necessarily soon reach the statical condition in which all the income is absorbed in simply taking care of what has been accumulated.

Congress rejected, one after the other, the schemes for making of the Institution an observatory, a library, a normal school, and a lecturing establishment, with professors at Washington. It created a Board of Regents, charged it with the care of the collections and museums belonging to the United States; authorized the expenditure, if the Regents saw fit, of a sum not exceeding twenty-five thousand dollars annually for the formation of a library; and in all else it directed them to make such disposal of the income "as they shall deem best suited for the promotion of the purpose of the testator."

Under this charter, and with the course of the Institution still to be marked out, it is not surprising that the official adviser and executive of the Board should look to the will of Smithson for the controlling interpretation of the law. He knew, moreover, that in an earlier will

Smithson had bequeathed his fortune to the Royal Society of London, an institution expressly for the furtherance of scientific research; and that he changed, as we may say, the trusteeship for a purely personal reason. HENRY took his stand on the broad and simple terms of the bequest, "for the increase and diffusion of knowledge among men." And he never—

Narrowed his mind,
And *to locality* gave what was meant for mankind.

He proposed only one restriction, of obvious wisdom and necessity, that, in view of the limited means of the Institution, it ought not to undertake anything which could be done, and well done, by other existing instrumentalities. So, as occasion arose, he lightened its load and saved its energies by giving over to other agencies some of its cherished work—meteorology, for instance, in which a most popular bureau now usefully expends many times more than the whole Smithsonian income.

He has in these last years signified his desire to go still further in this direction, and to have the Institution relieved from the charge of the National Museum, now of imperial dimensions and importance. His reasons were summed up in few words in his last report, along with his synopsis of the appropriate functions of the Institution, which he prays may not be merged in or overshadowed by any establishment of the Government, but may stand "free to the unobstructed observation of the whole world, keeping in perpetual remembrance the will of its founder." Its true functions he declares are:

"First. To enlarge the bounds of human thought by assisting men of science to make original investigations in all branches of knowledge; to publish these, and to present copies to all the principal libraries of the world. Second. To institute investigations in various branches of science, and explorations for the collection of specimens in natural history and ethnology, to be distributed to museums and other establishments. Third. To diffuse knowledge by carrying on an extended international series of exchanges by which the accounts of all the original researches in science, the educational progress, and the general advance of civilization in the New World are exchanged for similar works of the Old World."

The plan which our late Secretary originated has commended itself to the judgment of successive Boards of Regents, and, we may be permitted to add, is now approved wherever it is known and understood.

Professor HENRY took his full share of the various honorable duties to which such men are called. He was in his turn President of the American Association for the Advancement of Science, in the year 1849;

of the Society for the Advancement of Education, in 1855; a Trustee of Princeton College, and of Columbian University, also of the Corcoran Gallery of Art, in which the Smithsonian Institution deposits its art collections; Visitor of the Government Hospital for the Insane; President of the Philosophical Society of Washington; President of the National Academy of Sciences at Washington. For many years a member of the Light-House Board, to which he gave gratuitous and invaluable services as Chairman of its committee on experiments, he added for the last seven years the chairmanship of the board itself, in his administration no sinecure. Advice and investigation were sought from him, from time to time, by every department of Government. All were sure that his advice was never biased by personal interest; and his sound judgment, supported by spotless character, was greatly deferred to.

We have said that in coming to Washington a career of investigation was exchanged for a life of administration. It should rather be said that his investigations thereafter took a directly practical turn, as his mind was brought to bear upon difficult questions of immediate importance which were referred to him by Government or came in the course of official duty. In the light-house service alone his timely experiments upon lard-oil lighting, and the firmness with which he pressed his conclusions into practice when sperm-oil became dear, has already saved more than a million of dollars; the adaptation of mineral oil to the lesser lights made another great saving; and the results reached by his recent investigations of the conditions which influence the transmission of sound and their application to acoustical signaling are not to be valued by the saving of money only.

It was in the prosecution of these last investigations, over a year ago, and probably in consequence of exposure in them, at the light-house station on Staten Island, that an intimation of the approaching end of these labors was received. Yet a few months more of useful life were vouchsafed to him, not free from suffering, but blessed with an unclouded mind and borne with a serene spirit; and then, at midday on the 13th of May last, the scene was closed.

At the sepulture of his remains (on the 16th) and afterward, it was generally remarked at Washington that never before had the funeral of a private citizen called forth such sense of loss, such profound demonstrations of respect and affection.

It is not for us to assign Professor HENRY'S place among the men of science of our time. Those who do this will probably note that his

American predecessors were Franklin and Rumford; that all three were what we call self-made men; that all three, after having proved their talents for original investigation in physics, were called in their mature years to duties of administration and the conduct of affairs. There are interesting parallels to be drawn from their scientific work, if one had time to trace them.

Not often is a great man of science a good man of business. HENRY'S friends at Princeton, who besought him not to abandon the peaceful academic life which he was enjoying and the quiet pursuits which had given him fame, were surprised when in another sphere he developed equal talents for organization and administration. We have seen how he always developed the talent to do wisely and well whatever he undertook. His well-poised spirit, at once patient and masterful, asserted itself in the trials he encountered in the early years of the Institution, and gave assurance that he could deal with men as well as with the forces of nature.

Again, not often is a man of science free from the overmastering influence of his special pursuit. More or less his "nature is subdued to what it works in, like the dyer's hand." Now, HENRY'S mind was uncolored by the studies of his predilection. His catholic spirit comes out in his definition of science: "Science is the knowledge of the laws of phenomena, whether they relate to mind or matter." It appears in his choice of the investigations to be furthered and memoirs to be published by the Institution. These nowhere show the bias of a specialist.

Then, he was a careful, painstaking man, very solicitous—perhaps unduly anxious—about the particulars of everything for which he felt responsible. Therefore he was sometimes slow in making up his mind on a practical question. May we here condescend to a trivial anecdote of his early boyhood, which he amusingly related to one of us many years ago and pleasantly recalled at one of our latest interviews. It goes back to the time when he was first allowed to have a pair of boots, and to choose for himself the style of them. He was living with his grandmother in the country, and the village Crispin could offer no great choice of patterns; indeed, it was narrowed down to the alternative of round toes or square. Daily the boy visited the shop and pondered the alternatives, even while the manufacture was going on, until at length the shoemaker, who could brook no more delay, took the dilemma by both horns and produced the most remarkable pair of boots the wearer ever had; one boot round-toed, the other square-toed.

Deliberate as HENRY was in after years, taught by this early lesson, he probably never again postponed decision till it was too late to choose. One result of due deliberation was that he rarely had to change his mind. When he had taken his course, he held to it. His patience and kindness under demands upon his time were something wonderful. Some men are thus patient from easy good-nature; HENRY was so from principle. A noticeable part of the Secretary's correspondence was with a class of men—more numerous than would be supposed—who thought they had discovered new laws of nature or new applications of them, and who appealed to him to make their discoveries known. The Secretary never returned a curt answer to such appeals or inquiries, whether made personally or by letter. Many are the hours which he would conscientiously devote to such paradoxical schemes—sometimes of wonderful ingenuity—and to the dictation of elaborate replies to them. Detecting far down in the man's mind the germs of the fallacy which had misled him, he would spare no pains to present it and its consequences so plainly to his bewildered correspondent that he could find his own way out of it; while at the same time he awarded credit and encouragement for whatever was true, probable, or ingenious.

Although of sensitive spirit and with a just sense of what was due to himself, Professor HENRY kept free from controversy. Once he took up the pen, not because his discoveries were set at naught, but because his veracity was impliedly assailed. His dignified recital of undeniable facts (in his Annual Report for 1857) was all that was necessary, and not even a word of indignant comment was added.

He left his scientific work to form its part of the history of science and to be judged by scientific men. The empiric he once sententiously defined to be "one who appeals his cause to an incompetent tribunal." He never courted publicity; not from fastidious dislike, still less from disdain of well-earned popular applause, but simply because he never thought of it.

His disinterested devotion to this Institution was shown in many ways; among others in successive refusals to accept increase of salary lest it should be thought that the office he held was lucrative. Twice or thrice, moreover, while cumbered with anxieties, he promptly declined calls to positions of greater emolument, less care, and abundant leisure for the pursuits he loved.

We cannot here continue these delineations, and it may be that the character of the man has portrayed itself in general outlines as the narrative proceeded. But one trait may not be wholly omitted from the biography of one who has well been called "the model of a Christian gentleman," and who is also our best example of a physical philosopher. His life was the practical harmony of the two characters. His entire freedom from the doubts which disturb some minds is shown in that last letter which he dictated, in which he touches the grounds of faith both in natural and revealed religion; also in his sententious declaration upon some earlier occasion, that the person who thought there could be any real conflict between science and religion must be either very young in science or ignorant of religion.

The man for whom this memorial is placed was a veteran in both; was one of that noble line of natural philosophers for whom we may in all sincerity render to Almighty God hearty thanks, not only for the good example and fruit of their lives, but also that, having finished their course in faith, they do now rest from their labors.

SUPPLEMENTARY NOTES.

NOTE I.

SEQUENCE OF DISCOVERY AND INVENTION RESULTING IN THE ELECTRO-MAGNETIC TELEGRAPH.

The following appear to be the main points in the order of discovery which led to the electro-magnetic telegraph. They are here condensed from Professor Henry's "Statement", in the "Proceedings of the Regents", published in the Smithsonian Report for the year 1857, and from a note appended by Mr. William B. Taylor to his "Memoir of Joseph Henry and his Scientific Work," read before the Philosophical Society of Washington.

1819–1820. Oersted showed that a magnetic needle is deflected by the action of a current of galvanic electricity passing near it. It appears that this discovery had already been made as early as the year 1802, by Romagnesi, and published in 1805.

1820. Arago discovered that while a galvanic current is passing through a copper wire it is capable of developing magnetism in soft iron.

1820. Ampère discovered that two wires through which currents are passing in the same direction attract, and in opposite directions repel, each other; and thence he inferred that magnetism consists in the attraction of electrical currents revolving at right angles to the line joining the two poles of the magnet, and is produced in a bar of steel or iron by induction from a series of electrical currents revolving in the same direction at right angles to the axis of the bar.

1820. Schweigger in the same year produced the galvanometer.

1825. Sturgeon made the electro-magnet by bending the bar, or rather a piece of iron wire, into the form of a horse-shoe, covering it with varnish to insulate it, and surrounding it with a helix of wire the turns of which were at a distance.

1829–1830. Henry, in accordance with the theory of Ampère, produced the intensity or spool-wound magnet, insulating the wire instead of the rod or bar, and covering the whole surface of the iron with a series of coils in close contact. He extended the principle to the full by winding successive strata of insulated wire over each other, thus producing a compound helix formed of a long wire of many coils. At the same time he developed the relation of the intensity magnet to the intensity battery, and their relations to the magnet of quantity. He thus made the electro-magnet capable of transmitting power to a long distance, demonstrated the principle and perfected the magnet applicable to the purpose, was the first actually to magnetize a piece of iron at a distance, and to demonstrate and declare the applicability of the electro-magnet to telegraphy at a distance. Using the terminal short-circuit magnet of quantity and the armature as the signaling device, he was the first to make by it acoustic signals, sounding a bell at a distance by means of the electro-magnet.

1833. Weber discovered that the conducting-wires of an electric telegraph could be left without insulation except at the points of support.

1833. Gauss ingeniously arranged the application of a dual sign in such manner as to produce a true alphabet for telegraphy.

1836. Daniel invented and brought into use a constant galvanic battery.

1837. Steinheil discovered that the earth may form the returning half of the circuit, so that a single conducting wire suffices for telegraphy.

1837. Morse adopted, through the agency of Dr. Gale, the principle of the Henry electro-magnet, and the armature made of a recording instrument.

1838. Morse devised his "dot and dash" alphabet, a great improvement upon the Gauss and Steinheil alphabets.

1844. Morse suggested and brought into use the system of relay-magnets, and relay-circuits, to re-einforce the current.

NOTE II.

LETTER FROM PROFESSOR HENRY TO THE REV. S. B. DOD, GIVING A SKETCH OF SCIENTIFIC RESEARCHES AT PRINCETON.

[From the Princeton Memorial of Professor Henry.]

MY DEAR SIR: In compliance with your request that I would give an account of my scientific researches during my connection with the College of New Jersey, I furnish the following brief statement of my labors within the period mentioned:

I. Previous to my call from the Albany Academy to a professorship in the College of New Jersey, I had made a series of researches on electro-magnetism, in which I developed the principles of the electro-magnet and the means of accumulating the magnetic power to a great extent, and had also applied this power in the invention of the first electro-magnetic machine; that is, a mechanical contrivance by which electro-magnetism was applied as a motive power.

I soon saw, however, that the application of this power was but an indirect method of employing the energy derived from the combustion of coal, and, therefore, could never compete, on the score of expense, with that agent as a means of propelling machinery, but that it might be used in some cases in which expense of power was not a consideration to be weighed against the value of certain objects to be attained.

A great amount of labor has since been devoted to this invention, especially at the expense of the Government of the United States, by the late Dr. Page, but it still remains in nearly the same condition it was left in by myself in 1831.

I also applied, while in Albany, the results of my experiments to the invention of the first electro-magnetic telegraph, in which signals were transmitted by exciting an electro-magnet at a distance, by which means bells were struck in succession, capable of indicating letters of the alphabet.

In the midst of these investigations I was called to Princeton, through the nomination of Dr. Jacob Green, then of Philadelphia, and Dr. John Torrey, of New York.

I arrived in Princeton in November, 1832, and as soon as I became fully settled in the chair which I occupied, I recommenced my investigations, constructed a still more powerful electro-magnet than I had made before—one which would sustain over 3,000 pounds—and with it illustrated to my class the manner in which a large amount of power might, by means of a relay-magnet, be called into operation at the distance of many miles.

I also made several modifications in the electro-magnetic machine before mentioned, and just previous to my leaving for England, in 1837, again turned my attention to the telegraph. I think the first actual line of telegraph using the earth as a conductor, was made in the beginning of 1836. A wire was extended across the front campus of the college grounds, from the upper story of the library building to the philosophical hall on the opposite side, the ends terminating in two wells. Through this wire, signals were sent from time to time from my house to my laboratory. The electro-magnetic telegraph was first invented by me, in Albany, in 1830. Professor Morse, according to his statements, conceived the idea of an electro-magnetic telegraph in his voyage across the ocean in 1832, but did not until several years afterward—1837—attempt to carry his ideas into practice; and when he did so, he found himself so little acquainted with the subject of electricity that he could not make his simple machine operate through the distance of a few yards. In this dilemma he called in the aid of Dr. Gale, who was well acquainted with what I had done in Albany and Princeton, having visited me at the latter place. He informed Professor Morse that he had not the right kind of a battery nor the right kind of magnets, whereupon the professor turned the matter over to him, and, with the knowledge he had obtained from my researches, he was enabled to make the instrument work through a distance of several miles. For this service Professor Morse gave him a share of his patent, which he afterwards purchased from him for $15,000. At the time of making my original experiments on electro-magnetism in Albany, I was urged by a friend to take out a patent, both for its application to machinery and to the telegraph, but this I declined, on the ground that I did not then consider it compatible with the dignity of science to confine the benefits which might be derived from it to the exclusive use of any individual. In this, perhaps, I was too fastidious. In briefly stating my claims to the invention of the electro-magnetic telegraph, I may say I was the first to bring the electro-magnet into the condition necessary to its use in telegraphy, and also to point out its application to the telegraph, and to illustrate this by constructing a working telegraph, and, had I taken out a patent for my labors at that time, Mr. Morse could have had no ground on which to found his claim for a patent for his invention. To Mr. Morse, however, great credit is due for his alphabet, and for his perseverance in bringing the telegraph into practical use.

II. My next investigation, after being settled at Princeton, was in relation to electro-dynamic induction. Mr. Faraday had discovered that when a current of galvanic electricity was passed through a wire from a battery, a current in an opposite direction was induced in a wire arranged parallel to this conductor. I discovered that an induction of a similar kind took place in the primary conducting wire itself, so that a current which, in its passage through a short wire conductor, would neither produce sparks nor shocks, would, if the wire were sufficiently long, produce both these phenomena. The effect was most strikingly exhibited when the conductor was a flat ribbon, covered with silk, rolled into the form of a helix. With this, brilliant deflagrations and other electrical effects of high intensity were produced by means of a current from a battery of low intensity, such as that of a single element.

III. A series of investigations was afterward made, which resulted in producing inductive currents of different orders, having different directions, made up of waves alternately in opposite directions. It was also discovered that a plate of metal of any kind, introduced between two conductors, neutralized this induction, and this effect was afterward found to result from a current in the plate itself. It was afterward shown that a current of quantity was capable of producing a current of intensity, and, *vice versa*, a current of intensity would produce one of quantity.

IV. Another series of investigations, of a parallel character, was made in regard to ordinary or frictional electricity. In the course of these it was shown that electro-dynamic inductive action of ordinary electricity was of a peculiar character, and that effects could be produced by it at a remarkable distance. For example, if a shock were sent through a wire on the outside of a building, electrical effects could be exhibited in a parallel wire within the building. As another illustration of this, it may be mentioned that when a discharge of a battery of several Leyden jars was sent through the wire before mentioned, stretched across the campus in front of Nassau Hall, an inductive effect was produced in a parallel wire, the ends of which terminated in the plates of metal in the ground in the back campus, at a distance of several hundred feet from the primary current, the building of Nassau Hall intervening. The effect produced consisted in the magnetization of steel needles.

In this series of investigations, the fact was discovered that the induced current, as indicated by the needles, appeared to change its direction with the distance of the two wires, and other conditions of the experiment, the cause of which for a long time baffled inquiry, but was finally satisfactorily explained by the discovery that the discharge of electricity from a Leyden jar is of an oscillatory character, a principal discharge taking place in one direction, and immediately afterward a rebound in the opposite, and so on forward and backward, until the equilibrium is obtained.

V. The next series of investigations related to atmospheric induction. The first of these consisted of experiments with two large kites, the lower end of the string of one being attached to the upper surface of a second kite, the string of each consisting of a fine wire, the terminal end of the whole being coiled around an insulated drum. I was assisted in these experiments by Mr. Brown, of Philadelphia, who furnished the kites. When they were elevated, at a time when the sky was perfectly clear, sparks were drawn of surprising intensity and pungency, the electricity being supplied from the air, and the intensity being attributed to the induction of the long wire on itself.

VI. The next series of experiments pertaining to the same class was on the induction from thunder clouds. For this purpose the tin covering of the roof of the house in which I resided was used as an inductive plate. A wire was soldered to the edge of the roof near the gutter, was passed into my study and out again through holes in the window-sash, and terminated in connection with a plate of metal in a deep well immediately in front of the house. By breaking the continuity of that part of the wire which was in the study, and introducing into the opening a magnetizing spiral, needles placed in this could be magnetized by a flash of lightning so distant that the thunder could scarcely be heard. The electrical disturbance produced in this case was also found to be of an oscillatory character, a discharge first passing through the wire from the roof to the well, then another in the opposite direction, and so on until equilibrium was restored. This result was arrived at in this case, as well as in that of the Leyden jar, before mentioned, by placing the same, or a similar needle, in succession, in spirals of greater and greater numbers of turns; for example, in a spiral of a single turn the needle would be magnetized *plus*, or in the direction due to the first and more powerful wave. By increasing the number of coils, the action of the second wave became dominant, so that it would more than neutralize the magnetism produced by the first wave, and leave the needle *minus*. By farther increasing the number of turns, the third wave would be so exalted as to neutralize the effects of the preceding two, and so on. In the case of induction by lightning, the same result was obtained by placing a number of magnetizing spirals, of different magnetizing intensities, in the opening of the primary conductor, the result of which was to produce the magnetization of an equal number of needles, plus and minus, indicating alternate currents in opposite directions.

VII. In connection with this class of investigations a series of experiments was made in regard to lightning-rods. It was found that when a quantity of electricity was thrown upon a rod, the lower end of which was connected with a plate of metal sunk in the water of a deep well, that the electricity did not descend silently into water, but that sparks could be drawn from every part of the rod sufficiently intense to explode an electrical pistol, and to set fire to delicate inflammable substances. The spark thus given off was found to be of a peculiar character, for while it produced combustion and gave a slight shock, and fired the electrical pistol, it scarcely at all affected a gold-leaf electroscope. Indeed, it consisted of two sparks, one from the conductor and the other to it, in such quick succession, that the rupture of the air by the first served for the path of the second. The conclusion arrived at was, that during the passage of the electricity down the rod, each point in succession received a charge analogous to the statical charge of a prime conductor, and that this charge, in its passage down the rod, was immediately preceded by a negative charge; the two in their passage past the point at which the spark was drawn, giving rise to its duplex character. It was also shown by a series of experiments in transmitting a powerful discharge through a portion of air, that the latter, along the path of discharge, was endowed for a moment with an intense repulsive energy. So great is this that in one instance, when an electrical discharge from the clouds passed between two chimneys through the cockloft of a house, the whole roof was lifted from the walls. It is to this repulsive energy, or tendency in air to expand at right angles to the path of a stroke of lightning, that the mechanical effects which accompany the latter are generally to be attributed.

In connection with this series of investigations an experiment was devised for exhibiting the screening effect, within a space inclosed with a metallic envelope, of an exterior discharge of electricity. It consisted in coating the outside of a hollow glass globe with tinfoil and afterward inserting, through a small hole in the side, a delicate gold-leaf electrometer. The latter, being observed through a small opening in the tinfoil, was found to be unaffected by a discharge of electricity passed over the outside coating.

VIII. Another series of investigations was on the phosphorogenic emanation from the sun. It had long been known that, when the diamond is exposed to the direct rays of the sun, and then removed to a dark place, it emits a pale blue light, which has received the name of phosphorescence. This effect is not peculiar to the diamond, but is possessed by a number of substances, of which the sulphuret of lime is the most prominent. It is also well known that phosphorescence is produced by exposing the substance to the electric discharge. Another fact was discovered by Becquerel, of the French Institute, that the agent exciting phosphorescence traverses with difficulty a plate of glass or mica, while it is transmitted apparently without impediment through plates of black quartz impervious to light.

My experiments consisted, in the first place, in the reproduction of these results, and afterward in the extension of the list of substances which possess the capability of exhibiting phosphorescence, as well as the effects of different interposed media. It was found that, among a large number of transparent solids, some were permeable to the phosphorescing agent, and others impermeable, or imperfectly permeable. Among the former were ice, quartz, common salt, alum. Among the latter class, mica, tourmaline, camphor, &c. Among liquid permeable substances were water, solutions of alum, ammonia; while among the impermeable liquids were most of the acids, sulphate of zinc, sulphate of lead, alcohol, &c.

It was found that the emanation took place from every point of the line of the electric discharge, but with more intensity from the two extremities; and also, that the emanation producing phosphorescence, whatever be its nature, when reflected from a mirror, obeys the laws of the reflection of light, but no reflection was obtained from a surface of polished glass. It is likewise refracted by a prism of rock salt, in accordance with the laws of the refraction of light. By transmitting the rays from an electrical spark through a series of very thin plates of mica, it was shown that the emanation was capable of polarization, and, consequently, of double refraction.

IX. The next series of investigations was on a method of determining the velocity of projectiles. The plan proposed for this purpose consisted in the application of the instantaneous transmission of electrical action to determine the time of the passage of the ball between two screens, placed at a short distance from each other in the path of the projectile. For this purpose the observer is provided with a revolving cylinder moving by clock-work at a uniform rate, and of which the convex surface is divided into equal parts indicating a fractional part of a second. The passage of the ball through the screen breaks a galvanic circuit, the time of which is indicated on the revolving cylinder by the terminal spark produced in a wire surrounding a bundle of iron wires. Since the publication of this invention various other plans founded on the same principle have been introduced into practice.

X. Another series of experiments was in regard to the relative heat of different parts of the sun's disk, and especially to that of the spots on the surface. These were made in connection with Prof. S. Alexander, and consisted in throwing an image of the sun on a screen in a dark room by drawing out the eye-piece of a telescope. Through a hole in the screen the end of a sensitive thermo-pile was projected, the wires of which were connected with a galvanometer. By slightly moving the smaller end of the telescope different parts of the image of the sun could be thrown on the end of the thermo-pile, and by the deviation of the needle of the galvanometer the variation of the heat was indicated. In this way it was proved that the spots radiated less heat than the adjacent parts, and that all parts of the sun's surface did not give off an equal amount of heat.

XI. Another series of experiments was made with what was called a thermal telescope. This instrument consisted of a long hollow cone of pasteboard, lined with silver leaf and painted outside with lampblack. The angle at the apex of this cone was such as to cause all the parallel rays from a distant object entering the larger end of the cone to be reflected on to the end of a thermo-pile, the poles of which were connected with a delicate galvanometer. When the axis of this conical reflector was directed toward a distant object of greater or less temperature than the surrounding bodies, the difference was immediately indicated by the deviation of the needle of the galvanometer. For example, when the object was a horse in a distant field the radiant heat from the animal was distinctly perceptible at a distance of at least several hundred yards. When this instrument was turned toward the celestial vault the radiant heat was observed to increase from the zenith downward; when directed, however, to different clouds, it was found to indicate in some cases a greater and in others a less degree of radiation than the surrounding space. When the same instrument was directed to the moon a slight increase of temperature was observed over that of the adjacent sky, but this increase of heat was attributed to the reflection of the heat of the sun from the surface of the moon, and not to the heat of the moon itself. To show that this hypothesis is not inconsistent with the theory that the moon has cooled down to the temperature of celestial space, a concave mirror was made of ice, and a thermo-pile placed in the more distant focus. When a flame of hydrogen, rendered luminous by a spiral platinum wire, was placed in the other focus, the needle of the galvanometer attached to the pile indicated a reflection of heat, care being taken to shade the pile by a screen with a small opening introduced between it and the flame.

XII. Another series of experiments connected with the preceding may be mentioned here. It is well known that the light from a flame of hydrogen is of very feeble intensity. The same is the case with that of the compound blowpipe, while the temperature of the latter is exceedingly high, sufficiently so to melt fine platinum wire. It is also well known that by introducing lime or other solid substance into this flame its radiant light is very much increased. I found that the radiant heat was increased in a similar ratio, or, in other words, that in such cases the radiant heat was commensurate with the radiant light, and that the flame of the compound blowpipe, though of exceedingly high temperature, is a comparatively cool substance in regard to radiant heat. To study the relation of the temperature of a flame to the amount of heat given off, four ounces of water were placed in a platinum crucible and supported on a ring-stand over a flame of hydrogen; the minutes and seconds of time were then accurately noted which were required for the raising of the water from the temperature of 60° to the boiling point. The same experiment was repeated with an equal quantity of water, with the same flame, into which a piece of mica was inserted by a handle made of a narrow slip of the same substance. With this arrangement the light of the flame was much increased, while the time of bringing the water to the boiling point was also commensurately increased, thus conclusively showing that the increase of light was at the expense of the diminution of the temperature. These experiments were instituted in order to examine the nature of the fact mentioned by Count Rumford, that balls of clay introduced into a fire under some conditions increase the heat given off into an apartment. From the results just mentioned it follows that the increase in the radiant heat, which would facilitate the roasting of an article before the fire, would be at the expense of the boiling of a liquid in a vessel suspended directly over the point of combustion.

XIII. Another investigation had its origin in the accidental observation of the following fact: A quantity of mercury had been left undisturbed in a shallow saucer, with one end of a piece of lead wire, about the diameter of a goose-quill, and six inches long, plunged into it, the other end resting on the shelf. In this condition it was found, after a few days, that the mercury had passed through the solid lead, as if it were a siphon, and was lying on the shelf still in a liquid condition. The saucer contained a series of minute crystals of an amalgam of lead and mercury. A similar result was produced when a piece of the same lead wire was coated with varnish, the mercury being transmitted without disturbing the outer surface.

When a length of wire of five feet was supported vertically, with its lower end immersed in a vessel of mercury, the liquid metal was found to ascend, in the course of a few days, to a height of three feet. These results led me to think that the same property might be possessed by other metals in relation to each other. The first attempt to verify this conjecture was made by placing a small globule of gold on a plate of sheet-iron and submitting it to the heat of an assaying furnace, but the experiment was unsuccessful, for, although the gold was heated much beyond its melting point, it showed no signs of sinking into the pores of the iron. The idea afterward suggested itself that a different result would have been obtained had the two metals been made to adhere to each other, so that no oxide could form between the two surfaces. To verify this a piece of copper, thickly plated with silver, was heated to near the melting point of the metals, when the silver disappeared, and, after the surface was cleaned with diluted sulphuric acid, it presented a uniform surface of copper. This plate was next immersed for a few minutes in a solution of muriate of zinc, by which the surface of copper was removed and the surface of silver again exposed. The fact had long been observed by workmen in silver-plating that, in soldering the parts of plated metal, if care be not taken not to heat them unduly, the silver will disappear. This effect was supposed to be produced by evaporation, or the burning off, as it was called, of the plating. It is not improbable that a slow diffusion of one metal into the other takes place in the case of an alloy. Silver coins slightly alloyed with copper, after having lain long in the earth, are found covered with a salt of copper. This may be explained by supposing that the alloy of copper at the surface of the coin enters into combination with the carbonic acid of the soil, and, being thus removed, its place is supplied by a diffusion from within, and so on; it is not improbable that a large portion of the alloy may be removed in progress of time, and the purity of the coin be considerably increased. It is known to the jeweler that articles of copper plated with gold lose their brilliancy after a while, and that this can be restored by boiling them in ammonia. This effect is probably produced by the ammonia acting on the copper and dissolving off its surface so as to expose the gold, which by diffusion had penetrated into the body of the metal.

The slow diffusion of one metal into another at ordinary temperatures, would naturally require a long time to produce a perceptible effect, since it is probably only produced by the minute vibrations of the particles due to variations of temperature.

The same principle is applied to the explanation of the phenomenon called segregation—such as the formation of nodules of flint in masses of carbonate of lime; or, in other words, to the explanation of the manner in which the molecular action, which is insensible at perceptible distances, may produce results which would appear, at first sight, to be the effect of attraction acting at a distance.

XIV. Another series of experiments had reference to the constitution of matter in regard to its state of liquidity and solidity, and they had their origin in the examination of the condition of the metal of the large gun constructed under the direction of Captain Stockton, by the explosion of which several prominent members of the United States Government were killed at Washington. It was observed in testing the bars of iron made from this gun, that they varied much in tensile strength in different parts, and that, in breaking these bars, the solution of the continuity took place first in the interior. This phenomenon was attributed to the more ready mobility of the outer molecules of the bars, the inner ones being surrounded by matter incapable of slipping, and hence the rupture. A similar effect is produced in a piece of thick copper wire, each end, when broken, exhibiting, at the point of rupture, a cup-shaped surface, showing that the exterior of the metal sustained its connection longer than the interior. From these observations the conclusion was drawn, that rigidity differs from liquidity more in a polarity which prevents slipping of the molecules, than in a difference of the attractive force with which the molecules are held together; or that it is more in accordance with the phenomena of cohesion to suppose that, in the case of a liquid, instead of the attraction of the molecules being neutralized by heat, the effect of this agent is merely to neutralize the polarity of the molecules, so as to give them perfect freedom of motion around any imaginable axis. In illustration of this subject, the comparative tenacity of pure water and water in which soap had been dissolved was measured by the usual method of ascertaining the weight required to detach from the surface of each the same plate of wood, suspended from the beam of a balance, under the same condition of temperature and pressure. It was found, by this experiment, that the tenacity of pure water was greater than that of soap and water. This novel result is in accordance with the supposition that the mingling of the soap and the water interferes with the perfect mobility of the molecules, while at the same time it diminishes the attraction.

XV. A series of experiments was also made on the tenacity of soap in films. For this purpose sheets of soap-water films were stretched upon rings, and the attempt made to obtain the tenacity of these by placing on them pellets of cotton until they were ruptured. The thickness of these films was roughly estimated by Newton's scale of the colors of thin plates, and from the results the conclusion was arrived at that the attractive force of the molecules of water, for those of water, is approximately equal to that of the molecules of ice for those of ice, and that the difference in this case, of the solidity and liquidity, is due to the want of mobility in the latter, which prevented the slipping of the molecules on each other. It is this extreme mobility of the molecules of water that prevents the formation of permanent bubbles of it, and not a want of attraction.

The roundness of drops of water is not due to the attraction of the whole mass, but merely to the action of the surface, which in all cases of curvature is endowed with an intense contractile power.

This class of investigation also included the study of soap bubbles, and the establishment of the fact of the contractile power of these films. The curvature of the surface of a bubble tends to urge each particle toward the center, with a force inversely as the diameter. Two bubbles being connected, the smaller will collapse by expelling its contents into the larger. By employing frames of wire, soap bubbles were also made to assume various forms, by which capillarity and other phenomena were illustrated. This subject was afterward taken up by Plateau, of Ghent. Another part of the same investigation was the study of the spreading of oil on water, the phenomenon being referred to the fact that the attraction of water for water is greater than that of oil for oil, while the attraction of the molecules of oil for each other is less than the attraction of the same molecules for water; hence the oil spreads over the water. This is shown from the fact that when a rupture is made in a liquid compound, consisting of a stratum of oil resting on water, the rupture takes place in the oil, and not between the oil and water. The very small distance at which the attraction takes place, is exhibited by placing a single drop of oil on a surface of water of a considerable extent, when it will diffuse itself over the whole surface. If, however, a second drop be placed upon the same surface, it will retain its globular form.

XVI. Another contribution to science had reference to the origin of mechanical power and the nature of vital force. Mechanical power is defined to be that which is capable of overcoming resistance; or, in the language of the engineer, that which is employed to do work.

If we examine attentively the condition of the crust of the earth, we find it, as a general rule, in a state of permanent equilibrium. All the substances which constitute the material of the crust, such as acids and bases, with the exception of the indefinitely thin pellicle of vegetable and animal matter which exists at its surface, have all gone into a state of permanent combination, the whole being in the condition of a burnt slag of a furnace, entirely inert, and capable in itself of no change. All the changes which we observe on the surface of the globe may be referred to action from without, from celestial space.

The following is a list which will be found to include all the prime movers used at the present day, either directly or indirectly, in producing molecular changes in matter:

CLASS I.	Water power. Tide power. Wind power.	Immediately referable to celestial disturbance.
CLASS II.	Steam and other powers developed by combustion. Animal power.	Immediately referable to what is called vital action.

The forces of gravity, cohesion, electricity, and chemical attraction tend to produce a state of permanent equilibrium on our planet; hence these principles in themselves are not primary, but secondary, agents in producing mechanical effects. As an example, we may take the case of water-power, which is approximately due to the return of the water to a state of stable equilibrium on the surface of the ocean; but the primary cause of the motion is the force which produced the elevation of the liquid in the form of vapor—namely, the radiant heat of the sun. Also, in the phenomena of combustion, the immediate source of the power evolved in the form of heat is the passage from an unstable state into one of stable combination of the carbon and hydrogen of the fuel with oxygen of the atmosphere. But this power may ultimately be resolved into the force which caused the separation of these elements from their previous combination in the state of carbonic acid—namely, the radiant light of the sun. But the mechanical power exerted by animals is due to the passage of organized matter in the stomach from an unstable to a stable equilibrium, or as it were from the combustion of the food. It therefore follows that animal power is referable to the same source as that from the combustion of fuel—namely, developed power of the sun's beams. But according to this view, what is vitality? It is that mysterious principle—not mechanical power—which determines the form and arranges the atoms of organized matter, employing for this purpose the power which is derived from the food.

These propositions were illustrated by different examples. Suppose a vegetable organism impregnated with a germ—a potato, for instance—is planted below the surface of the ground in a damp soil, under a temperature sufficient for vegetation. If we examine it from time to time, we find it sending down rootlets into the earth and stems and leaves upward into the air. After the leaves have been fully expanded we shall find the tuber entirely exhausted, nothing but a skin remaining. The same effect will take place if the potato be placed in a warm cellar. It will continue to grow until all the starch and gluten are exhausted, when it will cease to increase. If, however, we now place it in the light, it will commence to grow again, and increase in size and weight. If we weigh the potato previous to the experiment and the plant after it has ceased to grow in the dark, we shall find that the weight of the latter is a little more than half that of the original tuber. The question then is, what has become of the material which filled the sac of the potato? The answer is, one part has run down into carbonic acid and water, and in this running down has evolved the power to build up the other part into the new plant. After the leaves have been formed and the plant exposed to the light of the sun, the developed power of its rays decomposes the carbonic acid of the atmosphere, and thus furnishes the pabulum and the power necessary to the further development of the organization. The same is the case with wheat and all other grains that are germinated in the earth. Besides the germ of the future plant, there is stored away around the germ the starch and gluten to furnish the power necessary to its development and also the food to build it up until it reaches the surface of the earth and can draw the source of its future growth from the power of the sunbeam. In the case of fungi and other plants that grow in the dark, they derive the power and the pabulum from surrounding vegetable matter in process of decay or in that of evolving power. A similar arrangement is found in regard to animal organization. It is well known that the egg continually diminishes in weight during the process of incubation, and the chick when fully formed weighs scarcely more than one-half the original weight of the egg. What is the interpretation of this phenomenon? Simply that one part of the contents of the shell has run down into carbonic acid and water, and thus evolved the power necessary to do the work of building up the future animal. In like manner when the tadpole is converted into a frog the animal for a while loses weight. A portion of the organism of its tail has been expended developing the power necessary to the transformation, while another portion has served for the material of the legs.

What, then, is the office of vitality? We say that it is analogous to that of the engineer who directs the power of the steam-engine in the execution of its work. Without this, in the case of the egg, the materials, left to the undirected force of affinity, would end in simply producing chemical compounds—sulphuretted hydrogen, carbonic acid, &c. There is no special analogy between the process of crystallization and that of vital action. In the one case definite mathematical forms are the necessary results, while in the other the results are precisely like those which are produced under the direction of will and intelligence, evincing a design and a purpose, making provision at one stage of the process for results to be attained at a later, and producing organs intended evidently for locomotion and perception. Not only is the result the same as that which is produced by human design, but in all cases the power with which this principle operates is the same as that with which the intelligent engineer produces his result.

This doctrine was first given in a communication to the American Philosophical Society in December, 1844, and more fully developed in a paper published in the Patent Office Report in 1857.

The publication in full of three of the series of investigations herein described was made in the Transactions of the American Philosophical Society. Others were published in Silliman's Journal, and both these are noticed in the Royal Society's Catalogue of Scientific Papers; but the remainder of them were published in the Proceedings of the American Philosophical Society, and are not mentioned in the work just referred to.

In 1846, while still at Princeton, I was requested by members of the Board of Regents of the Smithsonian Institution, which was then just founded, to study the will of Smithson, and to give a plan of organization by which the object of the bequest might be realized. My conclusion was that the intention of the donor was to advance Science by original research and publication; that the establishment was for the benefit of mankind generally, and that all unnecessary expenditures on local objects would be violations of the trust. The plan I proposed for the organization of the Institution was to assist men of science in making original researches, to publish these in a series of volumes, and to give a copy of these to every first-class library on the face of the earth.

I was afterward called to take charge of the Institution and to carry out this plan, which has been the governing policy of the establishment from the beginning to the present time.

One of the first enterprises of the Smithsonian Institution was the establishment of a system of simultaneous meteorological observations over the whole United States, especially for the study of the phenomena of American storms.

For this purpose the assistance of Professor Guyot was obtained, who drew up a series of instructions for the observers, which was printed and distributed in all parts of the country. He also recommended the form of instruments best suited to be used by the observers, and finally calculated, with immense labor, a volume of meteorological and physical tables for reducing and discussing observations. These tables were published by the Institution, and are now in use in almost every part of the world in which the English language is spoken. The prosecution of the system finally led to the application of the principles established to the predictions of the weather by means of the telegraph.

JOSEPH HENRY.

WASHINGTON, D. C., *December* 4, 1876.

NOTE III.

LIST OF PROFESSOR HENRY'S SCIENTIFIC PAPERS.

[Prepared by Wm. B. Taylor: Published in the Bulletin of the Philosophical Society of Washington, Vol. II.]

1825. On the Production of Cold by the Rarefaction of Air: accompanied with Experiments. (Presented Mar. 2.) Abstract, *Trans. Albany Institute*, vol. i. part ii. p. 36.

1827. On some Modifications of the Electro-magnetic Apparatus. (Read Oct. 10.) *Trans. Albany Inst.* vol. i. pp. 22–24.

1829. Topographical Sketch of the State of New York; designed chiefly to show the General Elevations and Depressions of its Surface. (Read Oct. 28.) *Trans. Albany Inst.* vol. i. pp. 87–112.

1829. First Abstract of Meteorological Records of the State of New York, for 1828. (In conjunction with Dr. T. Romeyn Beck.) *Annual Report of Regents of University*, to the Legislature of New York.—Albany, 1829.

1829. On the Mean Temperature of Twenty-seven different Places in the State of New York, for 1828. (In conjunction with Dr. T. Romeyn Beck.) Brewster's *Edinburgh Jour. Science*, Oct. 1828, vol. i. pp. 249–259.

1830. Second Abstract of Meteorological Records of the State of New York for 1829. (In conjunction with Dr. T. Romeyn Beck.) *Annual Report of Regents of University*, to the Legislature of New York.—Albany, 1830.

1831. On the Application of the Principle of the Galvanic Multiplier to Electro-magnetic Apparatus, and also to the development of great Magnetic power in soft iron, with small Galvanic Elements. Silliman's *American Jour. Science*, Jan. 1831, vol. xix. pp. 400–408.

1831. Tabular Statement of the Latitudes, Longitudes, and Elevations, of 42 Meteorological Stations in New York. *Annual Report Regents of University* to Legislature N. Y. 1831.

1831. Third Abstract of Meteorological Records of State of New York for 1830. (In conjunction with Dr. T. Romeyn Beck.) *Annual Report of Regents of University*, to the Legislature of New York.—Albany, 1831.

1831. An account of a large Electro-magnet, made for the Laboratory of Yale College. (In conjunction with Dr. Ten Eyck.) Silliman's *Am. Jour. Sci.* April, 1831, vol. xx. pp. 201–203.

1831. On a Reciprocating Motion produced by Magnetic attraction and repulsion. Silliman's *Am. Jour. Sci.* July, 1831, vol. xx. pp. 340–343. Sturgeon's *Annals of Electricity*, etc. vol. iii. pp. 430–432.

1832. On a Disturbance of the Earth's Magnetism in connection with the appearance of an Aurora as observed at Albany on the 19th of April, 1831. (Communicated to the Albany Institute, Jan. 26, 1832.) *Report of Regents of University*, to the Legislature of New York.—Albany, 1832. Silliman's *Am. Jour. Sci.* July, 1832, vol. xxii. pp. 143–155.

1832. Fourth Abstract of Meteorological Records of the State of New York for 1831. (In conjunction with Dr. T. Romeyn Beck.) *Annual Report of Regents of University*, to the Legislature of New York.—Albany, 1831.

1832. On the Production of Currents and Sparks of Electricity from Magnetism. Silliman's *Am. Jour. Sci.* July, 1832, vol. xxii. pp. 403–408.

1833. Fifth Abstract of Meteorological Records of the State of New York, for 1832. (In conjunction with Dr. T. Romeyn Beck.) *Annual Report of Regents of University*, to the Legislature of New York.—Albany, 1833.

1835. Contributions to Electricity and Magnetism. No. I. Description of a Galvanic Battery for producing Electricity of different intensities. (Read Jan. 14.) *Transactions Am. Philosoph. Society*, vol. v. pp. 217–222. Sturgeon's *Annals of Electricity*, etc. vol. i. pp. 277–281.

1835. Contributions to Electricity and Magnetism. No. II. On the influence of a Spiral Conductor in increasing the intensity of Electricity from a Galvanic arrangement of a single Pair, etc. (Read Feb. 6.) *Trans. Amer. Phil. Soc.* vol. v. pp. 223–232. Sturgeon's *Annals of Electricity*, etc. vol. i. pp. 282–290. Taylor's *Scientific Memoirs*, vol. i. pp. 540–547.

1835. Facts in reference to the Spark, etc. from a long Conductor uniting the poles of a Galvanic Battery. *Journal of Franklin Institute*, Mar. 1835, vol. xv. pp. 169, 170. *Silliman's Am. Jour. Sci.* July, 1835, vol. xxviii. pp. 327–331.

1837. A Notice of Electrical Researches, particularly in regard to the "lateral discharge." (Read before the British Association at Liverpool, Sept. 1837.) *Report Brit. Assoc.* 1837. Part II. pp. 22–24. Silliman's *Am. Jour. Sci.* April, 1838, vol. xxxiv. pp. 16–19.

1838. A Letter on the production directly from ordinary Electricity of Currents by Induction, analogous to those obtained from Galvanism. (Read to Philosoph. Society, May 4.) *Proceedings Am. Phil. Soc.* vol. i. p. 14.

1838. Contributions to Electricity and Magnetism. No. III. On Electro-dynamic Induction. (Read Nov. 2.) *Trans. Am. Phil. Soc.* vol. vi. pp. 303–338. Silliman's *Am. Jour. Sci.* Jan. 1840, vol. xxxviii. pp. 209–243. Sturgeon's *Annals of Electricity*, etc. vol. iv. pp. 281–310. *L. E. D Phil. Mag.* Mar. 1840, vol. xvi. pp. 200–210: pp. 254–265: pp. 551–562. Becquerel's *Traité expérimental de l'Electricité*, etc. vol. v. pp. 87–107. *Annales de Chimie et de Physique*, Dec. 1841, 3d series: vol. iii. pp. 394–407. Poggendorff's *Annalen der Physik und Chemie.* Supplemental vol. i. (Nach Band li.) 1842, pp. 282–312.

1839. A novel phenomenon of Capillary action: the transmission of Mercury through Lead. (Read Mar. 15.) *Proceedings Am. Phil. Soc.* vol. i. pp. 82, 83. Silliman's *Am. Jour. Sci.* Jan. 1839, vol. xxxviii. pp. 180, 181. *Biblioth. Universelle*, vol. xxix. pp. 175, 176. Liebig's *Annalen der Chemie*, etc. vol. xl. pp. 182, 183.

1839. A Letter on two distinct kinds of dynamic Induction by a Galvanic current. (Read to Phil. Soc. Oct. 18.) *Proceedings Am. Phil. Soc.* vol. i. pp. 134–136.

1839. Observations of Meteors made Nov. 25, 1835, simultaneously at Princeton and at Philadelphia, for determining their difference of Longitude. (In conjunction with Professors A. D. Bache, S. Alexander, and J. P. Espy.) *Proceedings Am. Phil. Soc.* Dec. 21, vol. i. pp. 162, 163. Silliman's *Am. Jour. Sci.* Oct. 1840, vol. xxxix. pp. 372, 373.

1840. Contributions to Electricity and Magnetism. No. IV. On Electro-dynamic Induction. (Read June 19.) *Trans. Am. Phil. Soc.* vol. viii. pp. 1–18. Silliman's *Am. Jour. Sci.* April, 1841, vol. xli. pp. 117–152. Sturgeon's *Annals Electricity*, etc. vol. vii. pp. 21–56. *L. E. D. Phil. Mag.* June, 1841, vol. xviii. pp. 482–514. *Annales de Chim. et Phys.* Dec. 1841, 3d ser. vol. iii. pp. 407–436. Poggendorff's *Annal. der Phys. und Chem.* 1841, vol. liv. pp. 84–97.

1840. Contributions to Electricity and Magnetism. No. IV,—continued. Theoretical Considerations relating to Electro-dynamic Induction. (Read Nov. 20.) *Trans. Am. Phil. Soc.* vol. viii. pp. 18–35.

1840. On the production of a reciprocating motion by the repulsion in the consecutive parts of a conductor through which a galvanic current is passing. (Read Nov. 20.) *Proceedings Am. Phil. Soc.* vol. i. p. 301.

1840. Electricity from heated Water. (Read Dec. 18.) *Proceedings Am. Phil. Soc.* vol. i. pp. 322–324.

1841. Description of a simple and inexpensive form of Heliostat. (Read Sept. 17.) *Proceedings Am. Phil. Soc.* vol. ii. p. 97.

1841. Observations on the effects of a Thunderstorm which visited Princeton on the evening of the 14th of July, 1841. (Read Nov. 5.) *Proceedings Am. Phil. Soc.* vol. ii. pp. 111–116.

1842. Résumé des Recherches faits sur les Courants d'Induction. *Archives de l'Electricité*, 1842, vol. ii. pp. 348–392.

1842. Contributions to Electricity and Magnetism. No. V. On Electro-dynamic Induction: and on the oscillatory discharge. (Read June 17.) *Proceedings Am. Phil. Soc.* vol. ii. pp. 193–196.

1843. On Phosphorogenic Emanation. (Read May 26.) *Proceedings Am. Phil. Soc.* vol. iii. pp. 38–44. Walker's *Electrical Magazine*, 1845, vol. i. pp. 444–450.

1843. On a new Method of determining the Velocity of Projectiles. (Read May 30.) *Proceedings Am. Phil. Soc.* vol. iii. pp. 165–167. Walker's *Electrical Magazine*, 1845, vol. i. pp. 250–352.

1843. Nouvelles Expériences sur l'Induction développée par l'Electricité ordinaire. (Translated.) *Archives de l'Electricité*, 1843, vol. iii. pp. 484–488.

1843. On the application of Melloni's thermo-electric apparatus to Meteorological purposes. (Presented orally Nov. 3.) *Proceedings Am. Phil. Soc.* vol. iv. p. 22.

1843. Theory of the discharge of the Leyden jar. (Presented Nov. 3.) *Proceedings Am. Phil. Soc.* vol. iv. pp. 22, 23.

1844. On the Cohesion of Liquids. (Read April 5.) *Proceedings Am. Phil. Soc.* vol. iv. pp. 56, 57. Silliman's *Am. Jour. Sci.* Oct. 1844, vol. xlviii. pp. 215, 216.

1844. On the Cohesion of Liquids,—continued. (Read May 17.) *Proceedings Am. Phil. Soc.* vol. iv. pp. 84, 85. Silliman's *Am.*

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1844. Syllabus of Lectures on Physics. Princeton, 8vo. 1844. Republished in part in *Smithsonian Report*, 1856, pp. 187–220.

1844. Classification and Sources of Mechanical Power. (Read Dec. 20.) *Proceedings Am. Phil. Soc.* vol. iv. pp. 127–129.

1845. On the Coast Survey. *Princeton Review*, April, 1845, vol. xvii. pp. 321–344.

1845. On the Relative Radiation of Heat by the Solar Spots. (Read June 20.) *Proceedings Am. Phil. Soc.* vol. iv. pp. 173–176. Brief Abstract in *Report Brit. Assoc.* 1845, Part II. p. 6. Walker's *Electrical Magazine*, 1846, vol. ii. pp. 321–324. Froriep's *Neue Notizen*, etc., No. 826, 1846, vol. xxxviii. col. 179–182. Poggendorff's *Annalen der Physik und Chemie*, 1846, vol. lxviii. pp. 102–104.

1845. On the Capillarity of Metals. (Read June 20.) *Proceedings Am. Phil. Soc.* vol. iv. pp. 176–178. Froriep's *Neue Notizen*, etc., No. 825, 1846, vol. xxxviii. col. 168–169. Poggendorff's *Annalen der Physik und Chemie.* 2d supplemental vol. (Nach Band lxxii.) 1848, pp. 358–361.

1845. On the Protection of Buildings from Lightning. (Read June 20.) *Proceedings Am. Phil. Soc.* vol. iv. p. 179. Silliman's *Am. Jour. Sci.* 1846, vol. ii. pp. 405, 406. Walker's *Electrical Magazine*, 1846, vol. ii. pp. 324–326. Froriep's *Neue Notizen*, etc., No. 823, 1846, vol. xxxviii. col. 133, 134.

1845. An account of peculiar effects on a house struck by Lightning. (Read June 20.) *Proceedings Am. Phil. Soc.* vol. iv. p. 180.

1845. On Color Blindness. *Princeton Review*, July, 1845, vol. xvii. pp. 483–489.

1845. On the discharge of Electricity through a long wire, etc. (Read Nov. 7.) *Proceedings Am. Phil. Soc.* vol. iv. pp. 208, 209.

1846. Repetition of Faraday's Experiment on the Polarization of Liquids under the influence of a galvanic current. (Read Jan. 16.) *Proceedings. Am. Phil. Soc.* vol. iv. pp. 229, 230.

1846. Extrait d'une Lettre à M. de la Rive, sur les Télégraphes Electriques dans les Etats-Unis de l'Amérique. *Biblioth. Universelle. Archives*, 1846, vol. ii. p. 178.

1846. Report on the action of Electricity on the Telegraph Wires: and Telegraph-poles struck by Lightning. (Read June 19.) *Proceedings Am. Phil. Soc.* vol. iv. pp. 260–268. Silliman's *Am. Jour. Sci.* 1847, vol. iii. pp. 25–32. *L. E. D. Phil. Mag.* 1847, vol. xxx. pp. 186–194. *Agricultural Report*, Commr. Pats. 1859, pp. 509–511.

1846. On the ball supported by a water jet: also experiments in regard to the "interference" of heat. (Read Oct. 16.) *Proceedings Am. Phil. Soc.* vol. iv. p. 285.

1846. On the corpuscular hypothesis of the constitution of Matter. (Read Nov. 6.) *Proceedings Am. Phil. Soc.* vol. iv. pp. 287–290.

1846. On the Height of Auroræ. (Read Dec. 3.) *Proceedings Am. Phil. Soc.* vol. iv. p. 370.

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1847. Article on "Magnetism" for the Encyclopædia Americana. *Encycl. Amer.* 1847, vol. xiv. pp. 412–426.

1848. On Heat.—A Thermal Telescope. Silliman's *Am. Jour. Sci.* Jan. 1848, vol. v. pp. 113, 114.

1848. Explanations and Illustrations of the Plan of the Smithsonian Institution. Silliman's *Am. Jour. Sci.* Nov. 1848, vol. vi. pp. 305–317.

1849. On the Radiation of Heat. (Read Oct. 19.) *Proceedings Am. Phil. Soc.* vol. v. p. 108.

1850. Analysis of the dynamic phenomena of the Leyden jar. *Proceedings Amer. Association*, Aug. 1850, pp. 377, 378.

1851. On the Limit of Perceptibility of a direct and reflected Sound. *Proceedings Amer. Association*, May, 1851, pp. 42, 43.

1851. On the Theory of the so-called Imponderables. *Proceedings Amer. Association*, Aug. 1851, pp. 84–91.

1853. Address before the Metropolitan Mechanics' Institute, Washingington. (Delivered March 19.) 8vo. Washington, 1853, 19 pp.

1854. Meteorological Tables of mean diurnal variations, etc. prepared as an Appendix to Mr. Russell's Lectures on Meteorology. *Smithsonian Report* for 1854, pp. 215–223.

1854. Thoughts on Education; an Introductory Discourse before the Association for Advancement of Education. (Delivered Dec. 28.) *Proceedings Assoc. Adv. Education*, 4th Session, 1854, pp. 17–31.

1855. On the mode of Testing Building Materials, etc. *Proceedings Am. Assoc.* Aug. 1855, pp. 102–112. Silliman's *Am. Jour. Sci.* July, 1856, vol. xxii. pp. 30–38; *Smithsonian Report*, 1856, pp. 303–310.

1855. On the effect of mingling Radiating Substances with Combustible Materials: (or incombustible bodies with fuel). *Proceedings Am. Assoc.* Aug. 1855, pp. 112–116.

1855. Account of Experiments on the alleged spontaneous separation of Alcohol and Water. *Proceed. Am. Assoc.* Aug. 1855, pp. 140–144.

1855. On the Induction of Electrical Currents. (Read Sept. 11.) *Proceedings Am. Academy of Arts*, etc. vol. iii. p. 198.

1855. Note on the Gyroscope. Appendix to Lecture by Prof. E. S. Snell. *Smithsonian Report*, 1855, p. 190.

1855. Remarks on Rain-fall at varying elevations. *Smithsonian Report*, 1855, pp. 213, 214.

1855. Directions for Meteorological Observations. (In conjunction with Prof. A. Guyot.) *Smithsonian Report*, 1855, pp. 215–244.

1855. Circular of Inquiries relative to Earthquakes. *Smithsonian Report*, 1855, p. 245.

1855. Instructions for Observations of the Aurora. *Smithsonian Report*, 1855, pp. 247–250.

1855. On Green's Standard Barometer for the Smithsonian Institution. *Smithsonian Report*, 1855, pp. 251–258.

1855. Circular of Instructions on Registering the periodical phenomena of animal and vegetable life. *Smithsonian Report*, 1855, pp. 259–263.

1855. Meteorology in its connection with Agriculture, Part I. *Agricultural Report* of Commr. Pats. 1855, pp. 357–394.

1856. On Acoustics applied to Public Buildings. *Proceedings Am. Assoc.* Aug. 1856, pp. 119–135. *Smithsonian Report*, 1856, pp. 221–234. *Canadian Journal*, 1857, vol. ii. pp. 130–140.

1856. Account of a large Sulphuric-acid Barometer in the Hall of the Smithsonian Institution Building. *Proceedings Am. Assoc.* Aug. 1856, pp. 135–138.

1856. Meteorology in its connection with Agriculture, Part II. General Atmospheric Conditions. *Agricultural Report* of Commr. Pats. 1856, pp. 455–492.

1857. Communication to the Board of Regents of the Smithsonian Institution, relative to a publication by Prof. Morse. *Smithsonian Report*, 1857, pp. 85–88.

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1857. Meteorology in its connection with Agriculture, Part III. Terrestrial Physics, and Temperature. *Agricultural Report* of Commr. Pats. 1857, pp. 419–506.

1858. Meteorology in its connection with Agriculture, Part IV. Atmospheric Vapor, and Currents. *Agricultural Report* of Commr. Pats. 1858, pp. 429–493.

1859. On Meteorology. *Canadian Naturalist and Geologist*, Aug. 1859, vol. iv. pp. 289–291.

1859. Application of the Telegraph to the Prediction of Changes of the Weather. (Read Aug. 9.) *Proceedings Am. Academy of Arts*, etc. vol. iv. pp. 271–275.

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GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1878.

The object of this appendix is to illustrate the operations of the Institution by reports of lectures and extracts from correspondence, as well as to furnish information of a character suited especially to the observers and other persons interested in the promotion of knowledge.

CONDORCET: A BIOGRAPHY.

BY M. ARAGO.

[Translated for the Smithsonian Institution by M. A. Henry.]

INTRODUCTION.

During the latter years of his life, George Cuvier consented to spare a few moments from his immortal researches to make some notes for the benefit of his future biographers. One of these notes commences thus: "I have written so many eulogies, that it is not presumptious to suppose that some one will write mine." This remark of the illustrious naturalist has reminded me that the last secretary of the old Academy of Sciences, himself the author of fifty-four biographies of academicians equally remarkable for their conception and their expression, has not yet received in this assembly the tribute which on many accounts is justly his due. The fact that we have owed this debt to his memory half a century is only a more powerful reason that it should be discharged without further delay. Our eulogies, as our memoirs, should have truth for their foundation and their object. But truth in regard to public men is difficult to attain, particularly when their lives have been passed in the midst of political storms. I therefore earnestly appeal to the few contemporaries of Condorcet whom death has spared, for correction of any error I may have made in spite of my careful efforts.

It has perhaps been observed that I have called my article a *biography* and not as usual an *historical eulogy*. It is in fact a detailed biography I have the honor to present to the Academy. Without desiring to establish a precedent for future secretaries, I will explain how in this instance the old form did not fulfil the end I desired.

Condorcet was no ordinary academician devoted alone to the labors of the closet: a speculative philosopher, and a citizen of unbiased judgment,—his life, his public and private conduct, and his works, were influential in literary, economical, and political associations. No one suffered more from the instability of public favor, jealousy, and fanaticism,—those three terrible scourges of reputation. In sketching a portrait, which it is my duty to render as faithful as possible, I cannot pretend to claim belief on mere assertion. It is not enough that for every characteristic feature I have endeavored with the greatest care to assure my own mind that my impressions are correct; I must enable the public to intelligently decide between the prevailing judgment and my own; it is necessary, therefore, to carefully examine and combat the false views of those who, in my estimation, have never truly comprehended the majestic aspect presented to his generation by the great Condorcet.

If I venture to hope that I have found truth where others have fallen into error, it is because I have had access to private sources of information. The distinguished daughter of our former secretary, and her illustrious husband, General O'Connor, have placed their rich archives at my disposal, with a kindness, unreserve, and liberality for which I cannot sufficiently thank them. Many manuscripts of Condorcet finished or incomplete, his letters to Turgot, answers from the lord lieutenant of Limoges, the comptroller-general of finance, fifty two unpublished letters of Voltaire, the correspondence of Lagrange with the secretary of the Academy of Sciences and with d'Alembert, letters of Frederick the Great, of Franklin, of Mademoiselle de l'Espinasse, of Borda, of Monge, &c.,—such are the treasures I received from the honorable family of Condorcet. This is the material which has led me to clear and precise ideas of the part taken by our confrère in the political, social, and intellectual movement of the second half of the eighteenth century.

I have a fear that I have not sufficiently avoided a temptation resulting from the kindness of General and Mrs. O'Connor. In going over the manuscript confided to me, my mind was involuntarily impressed with the apprehension of the thousand accidents which might happen to those precious pages, and the result has been an uncommon number of quotations, and therefore an expansion of points which perhaps might better have been only alluded to. I am aware of the inconvenience of such elaboration, but consider as sufficient compensation that I have perhaps rescued from oblivion facts, opinions, and literary judgments of great value; that I have made to speak in my place many eminent personages of the last century.

One word as to the unusual length of this article. I am well aware of the demands it must make upon the patient attention of my hearers, and the great desirability of retrenchment even after the numerous omissions which had become necessary by the exigencies of a public reading, but I consider my mission unusual, and more than ordinarily solemn; in fact I am about to undertake the rehabilitation of a colleague, and that in every point of view, scientific, literary, philosophical, and political. Any feeling of self-love that might interfere with this end would manifestly be unworthy of the assembly I address as well as of myself.

INFANCY AND YOUTH OF CONDORCET—HIS STUDIES, HIS CHARACTER, HIS MATHEMATICAL LABORS.

Jean Antoine Nicolas Caritat de Condorcet, formerly perpetual secretary of the Academy of Sciences, was born on the 17th of September, 1743, in Picardy, in the small village of Ribemont, which had already given to the Academy the engineer Blondel, celebrated by the construction of the gate of Saint Denis. The father of Condorcet, M. Caritat, a captain of cavalry, originally the Dauphin's, was the younger brother of the prelate whom we see successively from 1741 bishop of Gap, of Auxerre, and of Lisieux. He was also related to the cardinal of Bernis and the famous archbishop of Vienna, M. d'Yse of Saléon, who while bishop of Rodez made himself so prominent in the council of Embrun by his warm support of the Jesuits.

Condorcet had hardly attained his fourth year when he lost his father. The widow of Captain Caritat was very devotional in her tendencies. As, in her opinion, an infallible means of protecting her only son from the dangers of youth, she dedicated him to the Virgin and to the wearing of white garments. Condorcet accordingly wore for eight years the costume of a girl. This singular circumstance, as an effectual interdiction of all gymnastic exercises, retarded greatly the development of his physical powers. It also prevented him from entering the public schools, since a boy in petticoats could not fail to be an object of derision.

When he had attained his eleventh year, his uncle placed him under the care of one of the members of that celebrated Society of Jesus, around which began already to gather the political storm.

Not to trespass upon your time, permit me here a reflection. Madame Caritat de Condorcet, in the excess of her maternal love, subjected the childhood of the future secretary of the Academy to practices tending in more than one respect to superstition. The young Condorcet, as soon as he opened his eyes, was surrounded by a family composed of the highest dignitaries of the church and military officers, whose ideas were without exception aristocratic; his first guides, his first instructors, were Jesuits. Behold the result of so unusual a concourse of circumstances. In politics, a complete rejection of all idea of hereditary prerogative; in religion, scepticism carried to its utmost limits. This reflection confirmed by many observations of a similar character history can furnish, should it not calm somewhat the ardor with which political and religious parties, setting aside the rights of families, dispute by turns the monopoly of public instruction. Such a monopoly is dangerous only in a country where thought is chained; with the liberty of the press, reason, whatever may be done, will finally assert itself.

In the month of August, Condorcet, then thirteen years of age, carried off the second prize in the institution the Jesuits had established at Reims. In 1758 he commenced at Paris his mathematical studies, at the College of Navarre. His success was brilliant and rapid, for at the end of ten months he maintained a very difficult analytical thesis with so much distinction, that Clairaut, d'Alembert, and Fontaine, who examined him, saluted him as a future member of the Academy.

Such a horoscope from persons so eminent decided the future of the young mathematician. In spite of the resistance he foresaw on the part of his family, he resolved to devote himself to the pursuit of science, and established himself at Paris for the purpose with his old master, M. Giraud de Kéroudon.

When Condorcet left college he was already a profound thinker. I find in a letter of 1775, addressed to Turgot, and entitled *My confession of faith*, that at the age of seventeen years the young scholar had seriously reflected upon the moral ideas of justice and virtue, and upon the question whether (leaving aside other considerations) it was to man's interest to be just and virtuous. I give his solution of the question, although not sure of its originality with him. I am quite convinced, however, of the novelty of the extreme resolution to which it led him.

"A sentient being suffers from the evil which another sentient being experiences. In society, an unjust or criminal action cannot fail to injure some one. The author of such an action has, then, the consciousness of having caused suffering to one of his own kind. If the sensibility with which nature has endowed him remains intact, he must therefore suffer himself. In order, then, not to destroy his natural sensibility he must, in self-interest, strengthen his ideas of virtue and justice."

This conclusion followed naturally from the premises. It led the young Condorcet to renounce entirely the chase, and prevented him from killing even insects, provided that they did not harm him.

There were very few subjects in regard to which Condorcet had, even in early youth, vague and unformed opinions, and there is a beautiful harmony between the various periods of his laborious and agitated career. We see him, while still a youth, place kindness towards animals among the most efficacious means for preserving natural sensibility,—according to him, the principal source of all virtue. This idea controlled him throughout life. Even just before his death, in the admirable tract called *Advice of an outlaw to his daughter*, he writes these touching exhortations:

"My dear daughter, preserve in all its purity, all its force, the feeling which leads us to share the sorrow of every sentient being. Do not confine your sensibilities to the sufferings of the human race, but let your humanity extend even to animals; render those happy which belong to you; do not disdain to consider their well-being; be not insensible to their naive and sincere gratitude; cause them no useless pain. * * * The want of foresight in animals is the only excuse for that barbarous law which impels them to uselessly destroy each other."

I must seize the first opportunity which offers to show you Condorcet resolutely following these principles. Such as he was in morals we find him later in politics.

The first fruit of the meditations to which Condorcet devoted himself with M. Geraud de Kéroudon was a work entitled *Essay upon the integral calculus*. The author was only twenty-two when he presented it to the Academy. Allow me to preface with a few general reflections what I have to say of this treatise and of other mathematical works of Condorcet.

We can hardly mention in the vast domain of science more than eight or ten important discoveries which have not required the successive efforts of several generations of savans. Unhappily, inventors, from a mistaken feeling of self-love, are not ready to acknowledge to the historians of science the sources from which they have borrowed; they desire more to astonish than to instruct. They do not see it is far better to confess loyally their indebtedness than to incur the suspicion of bad faith.

In the sciences of observation every course of stones composing a complete edifice is more or less apparent. Books, academic collections, tell when and by whom these courses have been laid. The public may count the stages which must be surmounted by him to whom is reserved the happiness of laying the cap-stone. Each has his appropriate share of glory in the work of centuries.

Such is not the case with pure mathematics. The filiation of methods often escapes the most practised eye; at each step we find processes, theories without apparent connection with any which precede. Certain geometers move majestically in the upper regions of space, while it is not easy to say who prepared the road for their ascent. We may add that this road is usually established upon a scaffolding taken care of by no one when the road is completed. To collect scattered *débris* is a task unpleasant, ungrateful, and without glory, and, for this triple reason, is seldom undertaken.

The savans who devote themselves to pure mathematics without attaining the first rank must resign themselves to all these disadvantages. I have not yet mentioned the most important; it results from the necessity the historian of mathematics experiences of divesting his mind entirely of the light of his own century in judging of the works of former times. To this may be principally attributed the fact that Condorcet has never taken his true rank among geometers, and it is also on account of this difficulty that I have shrunk from the obligation of describing in a few lines the numerous mathematical works of our former secretary. Happily, as I have already said, I have in my hands unpublished articles of Lagrange, of d'Alembert, in which the memoirs of Condorcet are noticed at the time of their publication. Condorcet was thus judged by men of the utmost competence; an advantage by no means always secured to mathematical workers in the appreciation they receive from their contemporaries.

The first work of Condorcet, his *Integral calculus*, was examined by an academical committee, in May, 1765. The report of it, presented by d'Alembert, ends thus: "This work indicates great talent and deserves the approbation of the Academy."

Certain superficial critics, who scarcely looked at the work of Condorcet, spoke of it with ridicule and contempt, undoubtedly considering that the reporter of the academical committee treated it with culpable indulgence; and they seemed to have referred the matter to Lagrange, for this great geometer wrote to d'Alembert the 6th day of July, 1765: "The

Integral calculus of Condorcet appears to me well worthy of the praises with which you have honored it."

But setting these authorities aside, it is none the less established that this work contains the first serious well considered discussions of the conditions of integration of the ordinary differential equations of all orders, as well relatively to the integral of an immediately inferior order, as to the definitive integral. In it we also find the germs of several important works, since completed, on equations with finite differences.

The volume of the Academy of Sciences for 1772 contains the memoir in which the inventive spirit of Condorcet is most brilliantly manifested. The blind or systematic detractors of the mathematical ability of our former secretary are again controverted by the following verdict of Lagrange upon this production:

"The memoir is filled with great and fruitful ideas sufficient to have supplied the material for several works. The last article has especially impressed me by its elegance and utility. Recurrent series have so frequently been treated before, that the subject might have been considered exhausted. In this article, however, is a new application of these series, more important, in my opinion, than any which had been made before. It opens to us, so to say, a new field for the perfection of the Integral calculus."

Without leaving the field of pure mathematics, I might find in the academic collections of Paris, Berlin, Bologna, St. Petersburg, works bearing upon the most difficult questions of the science which would equally attest the ability of our former secretary, but I must hasten to notice some applications of analysis which did him no less honor. To do justice to the subject in any reasonable time I cannot proceed by order of date.

When we reflect upon the difficulties of all kinds astronomers have to overcome in order to determine with precision the orbits of the planets; when we consider, further, that it has been possible to harmonize the positions taken by the planets at the apogee, at the perigee, and all the intermediate points, only because they are constantly observable, we can hardly dare to conceive the hope of ever tracing in space the course of most of the comets, those vagrant stars which show themselves for a few days, only to be lost for centuries.

A very simple analytical calculus dissipates this impression. It shows that, speaking theoretically, three observations are more than sufficient to determine a comet's orbit, supposed to be parabolic, but the elements of this orbit are found to be so entangled in the equations that it appears difficult to free them without calculations of inconvenient length.

The problem thus regarded was not really solved, even after Newton, Fontaine, Euler, &c., had made it the subject of assiduous study. When the Academy of Berlin proposed it as a prize subject, the astronomers, instead of employing the methods of computation of these great geometers, still pursued the graphic systems, in which parabolas of card-board of various parameters are used. The aim of the Academy was clearly expressed—to have the processes employed, at once direct and simple. The award of the prize was to have been made in 1774, but it was deferred. In 1778 Condorcet shared it with M. Tempelhoff. "Your beautiful essay," wrote Lagrange to our confrère (June 8, 1778), "would have received the entire prize if the application of your theory had been made to any particular comet. This condition was in the programme." The condition was certainly there, but Condorcet had, as he himself acknowledges, an extreme repugnance "for calculations which tax without pleasing the attention." Of course it will be understood that numerical calculations are meant.

Among the great mathematical discoveries the world owes to France is a branch of calculus still very little appreciated, notwithstanding the services it has already rendered and those it still promises. This is the calculus of probabilities.

I do not hesitate to claim this discovery of the calculus of probabilities for our country, notwithstanding the efforts which have been made to deprive her of the credit. To dignify as inventors of this calculus the authors of some numerical remarks, without precision upon the various ways of computing a certain sum of points, in the simultaneous throw of three dice, would be a baseless pretension, which even national prejudice could hardly excuse.

Among the eminent services this calculus has rendered to mankind we should mention in the first line the abolition of the lottery and several other games of chance, which were as traps set for cupidity, credulity, and ignorance. Thanks to the evident and simple principles upon which the new analysis is founded, it is no longer possible to disguise the frauds in which these financial combinations were formerly entrenched: discounts, annuities, tontines, insurances of all kinds, have lost their character of mystery and obscurity.

On this ground the application of probabilities has been admitted without much resistance. But when Condorcet, after some essays of Nicolas Bernoulli, made incursion, by means of the new calculus, into the domain of jurisprudence and of moral and political science, an opposition almost general warned him that he could not take possession of this field without a severe contest. To tell the truth, the contest still continues. In order to end it, the geometers, on the one hand, must consent to put the principles of probabilities in clear, precise terms, as free as possible from technical expressions; while, on the other hand (and this is much more difficult), the public must be led to recognize, that appreciation of certain very complex matters cannot be attained at a glance; that it is impossible to speak pertinently of figures without mastering first at least the principles of enumeration; finally that there exist truths, legitimate connections, outside of those, the rudiments of which may have been acquired in youth, or by the reading of classical works. To comprehend that civil and criminal tribunals should be constituted so that the innocent may run very little risk of condemnation; in order also to comprehend that the chances of an unjust condemnation will be as much lessened as the judgment is rendered by the greater majority, the simple natural light of the most ordinary sentiments of humanity is all that is necessary. The problem becomes much more complicated when the question is to reconcile the proper guaranty of justice to the innocent with the need of society that the guilty shall not escape; simple reason here gives only vague results, to these calculation alone can give precision.

Let me repeat, that in judicial decisions there are certain phases, certain points of view, where resort may be had to calculation. By carrying into this labyrinth the torch of mathematical analysis, Condorcet not only proved his own courage, but opened an entirely new path. This, if pursued by geometers with a firm but cautious step, should lead to the discovery, in the social, judicial, and political organization of modern societies, of anomalies hitherto unsuspected.

It is quite evident that in its incursions into the domain of jurisprudence, the calculus of probabilities has for its object solely the numerical comparison of the decisions obtained with such or such a majority; to find the relative value of such or such number of witnesses. I may then in terms of severe reproof direct the attention of the public to the passages La Harpe, in his *Philosophie du XVIII Siècle*, has devoted to these applications of mathematics. It will be seen there, I dare say, with astonishment that the writer accuses our colleague of wishing to do away with testimony, and even written proof; of pretending to replace these advantageously by analytical formulæ. Instead of desiring to refute expressions so far from academical as "this is a supremely ridiculous use of science," it is "an extravagant conquest of the revolutionary philosophy," "this shows what insanity mathematics may produce," one regrets to see a man of real talent fallen into such incredible errors. As to the rest, it is a new proof that no one, not even an academician, can safely speak of that which he has not studied.

I must confess that the mathematical writings of Condorcet lack the elegant clearness which distinguish in so high a degree the memoirs of Euler and of Lagrange. D'Alembert, who was himself not irreproachable in this respect, endeavored, but with no great success, to induce our former secretary to take more pains. In March, 1772, he wrote to Lagrange: "I wish much that our friend Condorcet, who has so much sagacity, and such genius, had a better manner of expression, but it seems to be the nature of his mind to work in this way." This excuse for him has more foundation than might readily be accepted. Euler, d'Alembert, Lagrange, with an equal talent for mathematics, had each entirely different modes of working. Euler calculated without apparent effort, as men breathe, as the birds fly. In a letter I have under my eyes, dated 1769, d'Alembert thus speaks of himself to Lagrange: "It is not in my nature to occupy myself with one thing long at a time. I leave a subject and resume it again as often as the humor takes me, without discouragement, and ordinarily this intermittent perseverance is successful." A third way in which genius works seems to be indicated by this passage, which I copy from a manuscript note from the author of the *Mécanique analytique:* "My occupations are reduced to studying geometry tranquilly and in silence. As I am not pressed and work more for my own pleasure than from duty, like the lord of a chateau who builds, tears down, and rebuilds again, I make, unmake, and remake until I am tolerably content with the results, which, however, rarely happens." It is well, perhaps, that variety and individuality exist in mathematical researches, as in everything else; that ways the most diverse may equally lead men of ability to such discoveries as the mutual attraction of celestial bodies, the cause of the change in the obliquity of the ecliptic, the cause of the precession of the equinoxes, and that of the libration of the moon.

It may be asked with very natural surprise how Condorcet could renounce so easily the success a scientific career promised him in order to throw himself into the discussions of a subject often very problematical—social economy, and into the heated arena of politics. If this was a fault, many others also were equally culpable. Moreover, here is the palliation: Early convinced that the human race is indefinitely perfectible, Condorcet (I copy) regarded its improvement "as one of the pleasantest occupations, one of the first duties of the man who has strengthened his reason by study and meditation." He expressed the same thought in other words when, in a letter to Voltaire, he speaks with regret of returning to geometry: "It seems cold to work only for vainglory, when one desires to be working for the public good." I do not admit the distinction; the vainglory Condorcet speaks of was more directly conducive to the benefit of humanity than the researches, economical and philosophical, which our confrère undertook with so much zest in the social community. The good done by science has roots deeper and more extended than those from any other source. It is not subject to the fluctuations, the sudden caprices, the retrograde movements which so often produce perturbations in society. The torch of science dissipates a hundred old and debasing prejudices, inveterate maladies of the moral and intellectual world. If Condorcet was inclined to insinuate that scientific discoveries have no direct or immediate influence upon the body politic, I will not revert to such well-known benefactions as the mariner's compass, gunpowder, and the steam-engine to refute the suggestion; I will take one fact from a thousand that show what important events may result through the agency of the simplest inventions.

In the year 1746 the Pretender had appeared in Scotland, and France was sending him powerful succor. The French fleet and the English squadron passed each other during a very dark night. The most vigilant of the watch saw nothing, gave no signal; but, unhappily for France and its ally, Admiral Kowles, on leaving London, was provided with a glass of recent and very simple construction, known under the name of the *night-glass*—a glass in which the artist had sacrificed magnifying power to illumination. With this instrument he descried, outlined on the horizon, numerous vessels; he pursued them, reached them, captured them: the humble night-glass decided the destiny of the Stuarts.

We may explain the sadness felt by Condorcet on returning to mathematics by the fact that even the most illustrious of geometers were at that time discouraged. They believed that they had reached the final limits of the science. We may judge this from the following passage I copy from a letter of Lagrange to d'Alembert: "I believe that the mine is already too deep, and, as we discover no new branches, sooner or later it must be abandoned. Chemistry and physics proffer a richer reward, with easier research. The taste, too, of the century does not lie in our direction. It is not impossible that the pursuit of geometry in the academies will some time become as rare as the study of Arabic is to-day in the universities."

NOMINATION OF CONDORCET TO THE ACADEMY OF SCIENCES—HIS JOURNEY TO FERNEY—HIS RELATIONS WITH VOLTAIRE.

I learn by a letter from d'Alembert to Lagrange that Condorcet might have entered the Academy in 1768, at the age of twenty five years. His parents objected; to make science his official occupation was in their eyes derogatory to his station. He was received in 1769. His family yielded rather because tired of objecting than from conviction; for, six years later, Condorcet, already perpetual secretary of the Academy, wrote to Turgot, "Look with favor upon M. Thouvenel; he is the only one of my relatives who forgave me for not being a cavalry captain."

I must class among the first of Condorcet's academic works, an unpublished memoir upon the best organization of learned societies. This was intended for the Spanish Government. Influenced by the desire to calm the susceptibilities of the court of Madrid, the author has underrated certain phases of the question, but in it we find general views the fruit of an enlightened judgment and some curious anecdotes, which give the key, hitherto lost, to various provisions of our ancient academic rules.

It would show an entire want of understanding of the Spain of the XVIIIth century to dream of establishing an academy in which the Medina Celi, the d'Ossuna, &c., as representatives of the *nobility*, would have no place. Condorcet made this concession; he created honorary members, but stipulated for an equality of rights which would, he hoped, "*raise the academicians in the eyes of the public, and perhaps in their own estimation, for savans unfortunately are not always philosophers.*" "To render," said Condorcet, "this union of the men of rank, who love science, and the savans devoted to her progress agreeable to both parties, this saying of Louis XIV should be kept in mind: 'Do you know why Racine and M. de Cavoye agree so well? Racine with Cavoye is a man of the court; Cavoye with Racine is a man of letters.'"

Perhaps I may be excused if, in this connection, I divulge from the manuscript of Condorcet the origin of an article of the first charter of our society relating to the nomination of men of rank:

"When we introduced," said our confrère, "honorary members in the Academy, for fear that true savans might be troubled by the hauteur or abuse of power of the monks, Fontenelle proposed that the class of honorary members should be the only one to which they could be admitted."

In the hope of inducing the Spanish authorities not to be influenced in their choice of members by the religious principles of candidates, Condorcet proposed to them this question: "In an academy composed of the heathen Aristotle, the Brahmin Pythagoras, the Mussulman Alhasen, the Catholic Descartes, the Jansenist Pascal, the Ultramontane Cassini, the Calvinist Huygens, the Anglican Bacon, the Arian Newton, the Deist Leibnitz, would there be any question of preference in regard to sect? Think you there would be consideration in such an assembly for anything but pure geometry and physics?"

Condorcet aspired at Madrid not only to secure for the director of the academy extended authority and large prerogatives; he desired, to use his own words, "to free the savans from the indignity, especially distasteful to them, of being under the protection of subalterns—an evil, in fact, of all times and all countries."

If the memoir of Condorcet ever sees the day, it may be considered that he pronounced too absolutely against the admission of foreigners among the resident members of the academies. If so, history may say in his defense that when he wrote it, the French Government was prodigal of its favors to foreigners of moderate ability, while it neglected men of superior talent born in the country. Witness, for example, an Italian,—Boscovich, provided with a large pension by the same ministers who refused to d'Alembert, notwithstanding his genius, and contrary to all rule, the reversibility of 1,200 livres of revenue, proceeding from the succession of Clairaut. See also this same individual, who is mentioned very slightingly by Lagrange and d'Alembert in the letters I have in hand, attempting to enter the Academy without waiting for a vacancy and on the point of success, thanks to the foolish admiration entertained for any one with a foreign termination to his name.*

Until 1770 Condorcet seemed desirous of confining his attention exclusively to mathematical and economical studies. After this period he threw himself into the world of literature. There will be no hesitation in discerning the cause of this revolution, when we remark that it coincides in date with the journey made by d'Alembert and Condorcet to Ferney, the home of Voltaire. Upon his return the young academician of twenty-seven years wrote to Turgot, intendant of Limousin, "I found Voltaire so full of activity and enthusiasm that one would be tempted to believe him immortal, if a slight injustice towards Rousseau and too

*This paragraph scarcely does justice to the distinguished Italian physicist.

great sensibility in regard to the follies of Fréron did not prove him to be human." With reference to some articles in the *Dictionnaire philosophique* (then unpublished), articles the importance and originality of which may be a matter of doubt, Condorcet says: "Voltaire works less for reputation than for the good of his cause. He should not be judged as a philosopher but as an apostle." Could there be an appreciation of certain works of Voltaire of greater delicacy and taste?

Voltaire became a sort of Dalaï-Lama of the intellectual world. His friends were undignified courtiers, blindly devoted to the caprices of their master, and endeavoring to obtain, by outrageous flattery and unlimited complaisance, one of those letters from Ferney, which then seemed in the eyes of the world a certain token of immortality. As for Condorcet, a few words will show his opinion of this foolish adulation.

Madame Necker received in 1776 some very flattering verses from Voltaire. Her husband, successor of Turgot as comptroller-general of finances, received a large meed of praise also in these verses. All this was undoubtedly a matter of little consequence, but Condorcet's rigid sense of propriety was disturbed; he considered it an act of weakness, and feared that the reputation of the philosopher would suffer by it; his uneasiness and displeasure were vented in expressions of considerable severity. "I am sorry for these verses. You do not consider the weight of your name. * * * You are like that class of people who would leave a Jupiter to applaud a harlequin. * * * I know your piece only by hearsay, but those who have read it tell me that apropos of Mme. Enveloppe (M. and Mme. Necker) you speak of Cato. This reminds me of a young foreigner who once said to me, 'I have seen three great men in France, Voltaire, d'Alembert, and the Abbé de Voisenon.'"

One more example of his independence and loyal frankness: Voltaire was desirous of committing to the stage, at Paris, the tragedy he had composed in his old age, *Irene.* Condorcet, dreading a failure, resisted the pressing request of Voltaire to assist him in this step, with judicious and firm criticisms, couched in respectful language, however, in which is never lost the disciple addressing the master. Thus, for example, in a letter at the end of 1777: "See, sir! See! you have accustomed us to perfection in action and in character, as Racine has accustomed us to perfection in style. * * * If we are severe it is your own fault."

Condorcet was a profound geometer. He belonged to that class of intellectual men who, even when witnessing the most beautiful tragedies of Corneille and Racine, would mentally ask at each scene, what does that prove? Voltaire surely *ought to* have cared little for the criticism of a judge so incompetent. Listen and decide:

"FERNEY, *January* 12, 1778.

"MY UNIVERSAL PHILOSOPHER: Your discretion is astonishing and your friendship day by day more dear to me. I am grieved and ashamed to have differed from you in regard to the last effort of an old man of eighty-four years. I believed, upon the faith of a few tears shed in my presence by those who knew how to read and to assume without feeling passion, that if my little effort was well depicted and well acted it might produce at Paris a happy effect. I was, unfortunately, mistaken. I was aware of most of the faults you have the kindness to point out, and I add to them many others. I was endeavoring to make a picture out of a rough sketch, when your criticisms, dictated by friendship and by reason, came to increase my doubts of its worth. We can do nothing well in the arts of imagination and taste without the aid of an enlightened friend."

I feel that I am dwelling too long upon a point of the life of Condorcet which would seem to be already sufficiently illustrated, but I am irresistibly impelled to give a third and last incident of the frankness of Condorcet, which, in this case, truly amounted to a beautiful and noble action.

Voltaire and Montesquieu, did not like each other. Montesquieu even allowed this to be too evident. Voltaire, irritated by some pamphlets published by Montesquieu, wrote at Ferney, against the *l'Esprit des Lois*, several articles, which he sent to his friends in Paris, asking to have them published. Condorcet did not yield to the demand, imperious as it was, of the illustrious old man. "Do you not see," he remonstrated, "that to what you say to-day will be opposed your former praises of Montesquieu? His admirers, displeased by the way in which you take up some of his erroneous statements, will seek for similar inadvertencies in your own works, and they cannot possibly fail to find such, for even Cæsar describing his campaigns in his Commentaries, commits some inaccuracies. * * * You will, I hope, pardon me for not complying with your request in this matter, which you seem to have so much at heart. My attachment compels me to tell you what is for your advantage and not what will please you. If I loved you less, I would not dare to oppose you. I know the faults of Montesquieu, but he is worthy enough for you to overlook them." After this noble and loyal language, which was well calculated to rectify wrong ideas, it cannot be said that all the philosophers of the XVIIIth century were the vassals of Voltaire. The short response of the illustrious old man to the remonstrances of Condorcet is a document so valuable to the history of our literature that I cannot allow it to remain hidden in my portfolio; here it is:

"There is but one way to respond to what a true philosopher wrote me on the 20th of June. I thank him very sincerely. One ought not to blush to go to school, even if of the age of Methuselah * * * I repeat my thanks."

CONDORCET SUCCESSOR OF GRANDJEAN DE FOUCHY, AS SECRETARY OF THE ACADEMY OF SCIENCES—APPRECIATION OF HIS EULOGIES OF THE ACADEMICIANS.

Fontenelle had given so much éclat to the functions of the secretary of the Academy of Sciences that at his death no one wished to succeed him. After much solicitation, Mairan consented to occupy provisionally the place in order to allow the learned body time enough to make a choice they would not afterwards regret. It was finally concluded that the only way to avoid all disagreeable comparison, was to give to the nephew of Corneille a successor who would not aspire to imitate him, and who would disarm all criticism by his extreme modesty. It was under these circumstances that in 1743 Grandjean de Fouchy became the official organ of the old Academy.

Fouchy had occupied this position for more than thirty years when Condorcet entered the learned company. The infirmities of the perpetual secretary and his age made him desirous of a collaborator, and for this purpose he cast his eyes upon his youngest confrère. This was to create survivorship, to establish a precedent, and produced violent opposition in the Academy.

After an excitement rarely caused by the discussion of an abstract principle, the question finally stood as follows: The successor of Fontenelle, shall it be Bailly or Condorcet? The struggle could not fail to be noble and loyal in all that concerned these two gentlemen. Condorcet, throughout his life modest in the extreme, thought it necessary to give some evidence of his fitness for the place, of his facility in the art of writing, and undertook to compose some academic eulogies. The regulation of 1699 imposed upon the perpetual secretary the obligation of paying a tribute of respect to the memory of the academicians removed by death. This is the origin of the numerous biographies, often eloquent, always ingenious, left by Fontenelle, and confined all of them to the interval comprised between the last year of the XVIIth century and 1740. Fontenelle in his annals of the society does not take up the past, but commences only with the time of his entrance into office. The admirable collection he has left us, therefore, leaves a gap of thirty-three years. The academicians, deceased between 1666 and 1699, had no biographer, and it is in this third of a century that Condorcet found the subjects for the exercise of his pen, and among them such savans as Huygens, Roberval, Picard, Mariotte, Perrault, Roemer, &c. These, his first eulogies, are written with a profound knowledge of the subjects treated by the academicians, and in a simple, clear, and concise style. Condorcet said, in sending them to Turgot, "If I were able to give them more brilliancy of expression they would be more pleasing, but nature has not endowed me with the gift of such union of words. If I attempt anything of the kind, one word, astonished at another, starts back in affright to see itself so associated. I am humiliated before those whom in this respect nature has treated so much better than myself." Condorcet was mistaken in his low estimate of work which procured for him a large majority in the Academy, and of which Voltaire, d'Alembert, and Lagrange always spoke with great esteem. On the 9th of April, 1773, d'Alembert wrote to Lagrange, "Condorcet merited well the place of secretary on account of the excellent eulogies he has published of the academicians deceased since 1666. * * * They have had with us a complete success." "Your work," said Voltaire on the 1st of March, 1774, "is a monument to you. You always appear the master of those of whom you speak, but a master kind and modest; a king describing his subjects." Such commendation gave to these first essays of Condorcet a rank from which malevolence has in vain endeavored to reduce them.

Condorcet had hardly entered into his relation with M. de Fouchy, when he was commissioned to write several eulogies, among others that of the geometer Fontaine, deceased August 21, 1771. Difficulties unforeseen immediately assailed him. When he wrote the biographies of the earlier members of the Academy of Sciences a century had placed all things in their proper light—persons, labors, and discoveries,—and there was nothing for the writer to do but to express, in terms more or less happy, the irrevocable and already known decrees of posterity. Now he found himself in contact with the requirements, almost always blind, of families; with contemporary susceptibility sometimes of friends, always of rivals; finally with opinions based upon prejudice or personal animosity, than which nothing in the intellectual world is more difficult to eradicate. I suspect that Condorcet exaggerated somewhat these difficulties, although they were undoubtedly real, for he certainly spent an enormous amount of labor on his first eulogy of a contemporaneous academician. In his correspondence with Turgot we find him about the middle of 1772 already very busy with Fontaine. In the beginning of September he sent to the illustrious intendant a first copy of his work. The same eulogy, retouched and altered, in September, 1773, was on its way to Limoges. This, it must be admitted, was a long time to devote to an article of only twenty-five octavo pages. However, the maxim of Boileau was not in this instance without fruit. D'Alembert, writing to Lagrange, calls the eulogy of Fontaine a *chef-d'œuvre.* Voltaire says, in a letter of the 24th of December, 1773, "You have made me pass a half hour very agreeably. * * * You have relieved the dryness of the subject by a moral treatment noble and profound * * * which will delight all honest men. * * * If you need your copy I will return it to you, asking permission to make one for myself." Voltaire asking permission to copy for his own use a eulogy of Fontaine! Could there be a greater compliment than this?

To the eulogy of Fontaine succeeded that, not less piquant, not less ingenious, not less philosophic, of Condamine. The Academy and the public at large received it with unanimous applause. With the exception of the years 1775 and 1776, during which the Academy experienced no loss, the secretary had to provide annually until 1788, three, four, and even eight similar compositions. The style of these latter eulogies of Condorcet is grave and noble. There is in them no trace of affectation of manner or of effort; no desire to produce effect by expression, to cover, by striking or eccentric language, feebleness of thought.

Our confrère resisted with the more assurance the invasion of bad taste, the confusion of style, and the dithyrambic tendencies attempted by a certain school, because encouraged by Voltaire, who thus writes to him from Ferney, on the 18th of July, 1774: "It is without doubt a misfortune to be born in a century of bad taste, but what will you have? The public for eighty years have been content to drink bad brandy at their repasts."

It is now generally considered as a matter of hearsay that Condorcet lacked in his eulogies force, warmth, elegance, and sensibility. I differ from this opinion without fear of finding myself alone. In fact what have those who complain of his want of force to say to the following portrait of the academicians, happily few in number, whose names are connected with factious intrigue?

"Such intrigues have always been the work of those men tormented with the feeling of their own insignificance, who seek to obtain by noise what they fail to merit by worth, who having no right to reputation of their own, would destroy that merited by others, and overcome by petty malice the men of genius who oppress them with the weight of their renown."

To the critics who have accused Condorcet of a want of sensibility, I oppose the following passage from the unpublished eulogy of fathers Jacquier and Le Seur: * * * "Their friendship was not of that vulgar sort produced only by conformity of tastes and interests. It had its origin in a natural and irresistible attraction. In these deep and delicious friendships each endures the sufferings of his friend and enjoys all his pleasures. He has not a thought, he has not a sentiment, which his friend does not share; and if he is not always one with him, it is solely on account of the preference he gives him over himself. This friend is not only a man that one prefers to all other men, he is a being apart, whom none resembles; it is not his qualities, his virtues that one loves in him, for others may have these and yet not be loved the same; it is himself that one loves, and because it is himself. Those who have never experienced the sentiment can alone deny that it exists. * * * From the instant they encountered each other at Rome, everything was in common between them; troubles, pleasures, labors—glory even, the good, of all others, that two men very rarely share in good faith. Still each of them published separately a few articles, but these were of *little importance, and in the judgment of him to whom they belonged* not worthy to appear with the name of his friend. They desired perfect equality in the situations they occupied; if one obtained a distinction, he was not content until he had procured a similar honor for his friend. * * * *Father Jacquier had the misfortune to survive his friend.* Father le Seur succumbed to his infirmities in 1770. Two days before his decease he appeared to have lost all consciousness. 'Do you know me?' said Father le Jacquier to him a few moments before his death. 'Yes,' answered the dying man; 'I have just resolved a difficult equation with you.' Thus, in the midst of the destruction of his organs he had not forgotton the objects of his studies, and remembered the friend with whom he had all in common. Father Jacquier was forcibly taken from the arms of the dying man by the friends who, to use Jacquier's own expression, did not wish to lose them both. He resumed the chair his health had obliged him to vacate; caring little to prolong the days no longer brightened by friendship, he still wished to fill them with useful labor and thus divert the feelings of sorrow which nothing could cure. He knew better than to add the weight of time to that of grief. For minds that suffer, leisure is the most cruel torture."

The valuation Condorcet has given of the divers virtues of Condamine could, if we are not mistaken, be placed, without disadvantage, beside the eloquent speech Buffon addressed to the illustrious traveler on the day of his reception by the French Academy. It would bear as well comparison in elegance with the eulogy of the same academician, pronounced by the Abbé Delille, his successor.

The biographical compositions of Condorcet please because they contain what should naturally be their essence. The history of the human mind is in them viewed from a high standard. In the choice of details the author has constantly in view instruction and utility rather than entertainment. Without trespassing in the least upon truth, whose demands he places before every other interest or consideration, Condorcet is constantly ruled by the thought that the dignity of the savant is to a certain degree that of science; and that any applause which might be accorded to a witty portrayal of a ridiculous incident, would be a poor return for even a slight wrong done to the most modest branch of human knowledge.

We expect too much of *Monsieur plus que Fontenelle*, as Voltaire calls our confrère in several unpublished letters I have in hand, if we hope to find in his eulogies any chapters devoted entirely to the subsequent history of the sciences. Condorcet did not commit the error of giving to his auditors food stronger than they could digest.

Our former secretary was especially distinguished in his eulogies by the utmost impartiality, by philosophic thought, and by the interest he gave to the most simple biographical circumstances, by his constant abnegation of all personal feeling, of all party spirit, of all self-love. Condorcet described his own works, as well as those of Franklin, when he said of the latter: "We seek in them in vain for a line which could be suspected of having been written for his own glory."

The long career of Franklin certainly does not offer a better instance of frank, true modesty than is contained in this passage from the eulogy of Fontaine: "I thought, at one time, said this geometer, that a young man with whom I had been brought into connection had more talent and might attain greater eminence than myself. I was jealous of him, but I have not feared him since."—"The young man in question," added Condorcet, "is the author of this eulogy."

The class of the envious, always numerous and active, and ready to create disturbance, received through the mouth of Fontenelle a lesson of good sense and of wisdom, from which, unfortunately, they profited little. The first edition of Voltaire's Age of Louis XIV was about to appear. This was too good an occasion to irritate two great men against each other to be neglected. "How am I treated in this work?" asked Fontenelle. He was answered: "Voltaire commences by declaring that you are the only living person for whom he would make exception of the rule he had made for himself to speak only of the dead." "Stop," said the secretary of the Academy, "I do not wish to hear more. With anything Voltaire may add to that I must be content." Notwithstanding some criticism, Buffon, the immortal author of the *Histoire Naturelle*, would surely have been equally satisfied could he have heard the following tribute Condorcet renders to his eloquence: "The passages which escape from the pen of Buffon show the sensibility as well as the pride of his nature; but always controlled by a superior judgment, they make us feel, so to say, as if we were conversing with a pure intelligence, with only enough humanity to understand us and to be interested in our weakness. * * * Posterity will place the works of this great naturalist beside the dialogues of the disciple of Socrates and the teachings of the philosopher of Tusculum. * * * M. de Buffon, more varied, more brilliant, more prodigal of images than the two great representatives of Greece and Rome, joined facility to energy, grace to majesty. His philosophy, with a character less pronounced, is more varied and less melancholy. Aristotle seems to have written only for savants, Pliny for philosophers, M. de Buffon for all enlightened men."

After this quotation shall I injure Condorcet if I admit that Buffon never testified any kindness for him; that he was the most active friend of his rivals for the place of perpetual secretary of the Academy of Sciences and for that of member of the French Academy; that the idea of an academic censure, strongly recommended to the ministers of Louis XVI, and which constantly threatened the historian of our labors, originated with Buffon. It is worthy of note that the bickerings which at this time disturbed the Academy, as d'Alembert writes to Lagrange, on the 15th of April, 1775, to so great a degree "as to dishearten us for all serious study" and in which the illustrious naturalist took a prominent part, are revealed to us by the correspondence of La Harpe and numerous unpublished articles from other sources, but we seek in vain for any trace of them in the eulogies of the loyal secretary.

Fontenelle left a gap in his eulogies of deceased academicians, from 1699 to 1740; was this by design? One is tempted to think so, on observing among the omitted the Duke d'Escalonne, the famous Law and Père Gouye. I will leave no doubt of the kind in regard to Condorcet. If he did not make a eulogy of the Duke de La Vrillière, it was because in his eyes the title of honorary bestowed by the Academy did not render honorable the minister who all his life made a cruel and scandalous use of the *lettres de cachet.* His timid friends calculated with uneasiness the danger of irritating M. de Maurepas, prime minister and brother-in-law of M. de la Vrillière. Condorcet answered: "Would you prefer that I should be persecuted for a foolish act rather than for a just and moral one? Do you not think I will in the future be more easily pardoned for silence, than for speech, since I am resolved, if compelled to speak, to tell exactly the truth?"

EULOGY OF MICHEL DE L'HÔPITAL—LETTER OF A THEOLOGIAN TO THE AUTHOR OF THE DICTIONARY OF THREE CENTURIES—LETTER OF A LABORER OF PICARDY TO A. M. NECKER, PROHIBITIONIST—REFLECTIONS UPON THE COMMERCE IN GRAIN—NEW EDITION OF PASCAL'S THOUGHTS—ENTRANCE OF CONDORCET INTO THE FRENCH ACADEMY.

Hitherto we have followed step by step the geometer, the perpetual secretary of the Academy. Now we see our confrère throw himself with polemic ardor into literary and philosophical controversy, appearing before the public, often anonymously, in order, he said, not to add his personal enemies to the enemies of his cause. Condorcet was already by fair title secretary of our society when the French Academy issued as the subject for a competitive essay the eulogy of Michel de l'Hôpital. Captivated by the scope, the interest, and also the beauty of the theme, our confrère entered the lists with all the ardor natural to a young man of unknown antecedents and with a reputation to make. He did not obtain the prize, however; the preference was given to a paper, to-day completely forgotten, by the Abbé Remi. Some of the causes for his disappointment have become known to me, and it may perhaps be worth while to notice them.

What did the French Academy desire in proposing the eulogy of de l'Hôpital for a prize essay? A superficial review of the literary work of the illustrious chancellor, a general sketch of his political and administrative acts, a homage to his memory, written in a more or less florid or exalted style. To-day this kind of composition is little to the taste of the public; indeed what the celebrated assembly demanded could hardly be dignified with the name of a discourse.

It was not thus Condorcet regarded the subject presented to him. In his mind utility was preferred to every other merit. The life of l'Hôpital seemed to him to offer a salutary example to those finding themselves in difficult circumstances obliged to choose between repose and the public welfare. He did not hesitate as to the character of his essay. It was a history of the life, not merely a eulogistic notice of l'Hôpital, he felt impelled to write.

The life of l'Hôpital: but this is a history of a century of terrible events, of a long succession of shameful disorders, of barbarous and cruel actions, a century of intolerance and fanaticism. The field was large, but was not too much for the power, the knowledge, and the zeal of the writer. In his beautiful work Condorcet first shows us l'Hôpital in Italy, with the constable of Bourbon, in the parliament and council of Bologna. We then see him at the head of the finances. Later it is the chancellor, the minister, the statesman whose acts are revealed to the reader. The history of a life so full of incident could not properly be reduced to the limits of an article which could be read in sixty minutes—the time prescribed by the academy. Condorcet could not comply with this limitation, and his eulogy was three times longer than the programme allowed. This was sufficient in itself to make the rejection of the essay a foregone conclusion, to say nothing of the criticism the work excited in the literary Areopagus, of which the author of the Lyceum has preserved some specimens.

According to La Harpe, the style of the eulogy of l'Hôpital lacked harmony. The charge would have been a graver one had he said (if it could be said) that it lacked character, nerve, accuracy; that the ideas were neither new nor profound, and in that case it would be only necessary as a refutation to refer to such passages as the following:

"If Bertrandi (keeper of the seal of Henry II) has escaped the execration of succeeding centuries, it is because always petty even in the midst of his greatest power, always subaltern, even while occupying the highest places, he was too insignificant to attract attention."

"All the citizens wept over the ruin of their country. L'Hôpital alone did not despair. Hope never abandons noble souls. The love of the public good had with the chancellor all the characteristics, all the illusions of a veritable passion; l'Hôpital did not ignore obstacles, but felt his power to cope with them."

But "the obscurity of the style." In this criticism, I do not know what La Harpe means by "phrases which double upon each other." He is certainly clear enough, however, when he complains of Condorcet's want of dignity in speaking of vine-poles, billets of wood, and little pies, in the eulogy of a chancellor. We ought to hope in the spirit of loyalty that this remark of La Harpe's did not influence the decision of the Academy. Would you know where the expressions occur which made the critic so indignant? They are in a note, in which with reason the author denounces the strange, we might better say the deplorable regulations, which the prohibitive system suggested to even such minds as that of Michel de l'Hôpital. Yes, gentlemen; the fact cannot be denied; the virtuous chancellor prohibited the crying of little patties in the streets, in order—his words are unequivocal—to insure the pastry-shops from idleness and the people from indigestion. We may laugh in these days, we may be astonished, but none the less the sale of fagots, and vine-poles also, was forbidden. The laws of the time even determined the form of breeches and of farthingales. The fact that l'Hópital could approve such restrictions, shows clearly to what point even men of genius may yield to the influence of their century. But I do not know in truth what influence Condorcet would have obeyed if he had substituted elaborate phrases for the technical expressions that l'Hôpital, even with his poet hand, employed, if he had used ornamental style apropos of farthingales, of billets of wood, and little patties.

Voltaire certainly did not agree with La Harpe and his friends in their opinion of Condorcet, for, on the 3d of October, 1777, he writes to M. de Vaines, "I have just read, with great satisfaction, l'Hôpital, by Condorcet; all that he does bears the mark of a superior mind." I find expressions no less significant in an unpublished letter of Franklin: "I have read with extreme pleasure your excellent eulogy of l'Hôpital. I knew before that you were a great mathematician; now I consider you one of the first statesmen of Europe." Such praise is surely equal in value to an academic reward.

"The *Lettre d'un Théologien* to the author of the *Dictionnaire des trois Siècles* is one of the most piquant articles published for several years. This pamphlet, unaccompanied by the name of the author, has been generally attributed to the illustrious patriarch of Ferney. Never has he been more happy in his criticisms, never more good-natured in his raillery." It is in such terms that a correspondence since published and become celebrated announced, in 1774, the anonymous pamphlet of Condorcet.

Voltaire, to whom the authorship was then unknown, thus writes to our confrère on the 20th of August, 1774: "There are, in the *Letter of a Theologian*, passages of humor, as well as of eloquence, worthy of Pascal." He then proceeds to prove that, notwithstanding a prevalent opinion, the Abbé de Voisenon could not be the author of a piece so remarkable. As to himself (Voltaire), he ought not to be suspected of it, for the letter indicates a profound knowledge of mathematics; and, he adds, "In consequence of the trouble I experienced with the elements of Newton, I renounced, forty years ago, that class of studies."

The audacity of the *Letter of a Theologian*, since he was suspected of writing it, caused Voltaire great uneasiness, and he took every occasion to disown its authorship. "I do not wish," he said, "at the age of eighty-three to die elsewhere than in my bed." He thus speaks of it to M. d'Argental (August 17, 1774): "One could not be more eloquent nor yet more foolhardy. This work, as dangerous as it is admirable, will undoubtedly furnish means of attack to the enemies of philosophy. * * * I desire neither the glory of having written the *Letter of a Theologian* nor the punishment which will follow it. I am sorry that so good a cause has been injured by being defended with too much spirit." Again Voltaire writes: "How could any one dare, unless in command of two hundred thousand soldiers, to publish so audacious a work?"

If he took every occasion, as we have said, and every way to declare that he was not the author of the *Letter of a Theologian*, mark well, this was because he needed repose and feared persecution; not because his self-love was alarmed. He is evidently far from considering this supposition of the public injurious to him as a man of letters.

To such evidence as this would I call the attention of those who have considered Condorcet's style wanting in eloquence and depth.

In the society of d'Alembert our former confrère became a geometer. Turgot in his turn inspired him with a taste for social economy. Their ideas, their hopes, their sentiments became identical. It would really be impossible to mention a single point in science upon which Turgot and Condorcet differed, even in an almost imperceptible shade. They were both persuaded that in matters of commerce "entire and absolute liberty is the only law of utility and even justice." They believed that the protection accorded "to one special branch of industry was detrimental to all; * * * that the minute precautions with which legislators deemed it necessary to load their regulations were the fruits of timidity and ignorance, and without any compensation, the source of inconvenience, intolerable vexations, and real losses.

Turgot and Condorcet were, if possible, still more closely united upon the special question of commerce in grain. They maintained that entire liberty in this commerce was of equal importance to owners, to cultivators, to consumers, to employés; that there was no other remedy for the effects of local scarcity, no other means of reducing the mean price and diminishing the rate of variations, a matter of still more importance, for mean prices regulate the wages of the workmen. If, on the one hand, these rigorous principles were a formal discouragement to any yielding to disorderly clamors, or popular prejudices, on the other hand the two economists proclaimed distinctly that in times of scarcity the government ought to make provision for the poor. This relief should not, however, be dispensed blindly, but should be the price of work.

Turgot and his friend professed the maxim that there exist for every man certain natural privileges of which no lot in life can legitimately deprive him. They considered among the most important of these the *right to dispose of his own intelligence, his own hands, and his own labor.* Our philosophers also advocated the abolition of a number of tedious formalities, often absurd and always costly, which made the condition of the workmen an odious slavery. If the mastership and the wardenship were the despair of artisans and city workmen, the statutes of labor as severely affected the workmen of the rural districts. The labor statutes condemned to work without wages men who were dependent upon those very wages for their living. They allowed prodigality *in labor because this cost the royal treasury nothing. The form of the* requisitions, the hardness of the laws, the rigor of the penalties, added humiliation to misery. Turgot and Condorcet were the most ardent adversaries of this cruel servitude.

The two philosophers were not men who become tolerant of crime through seeing it constantly committed. The slave-trade excited their utmost abhorrence. If I had time and space I could here transcribe a quite recent letter from M. Clarkson, in which this venerable gentleman renders touching homage to the active efforts of Condorcet in behalf of the holy crusade against this cruel practice, which had absorbed his long life. It is therefore very appropriate that our David has placed among the bas-reliefs of his beautiful statue of Guttenberg the noble figure of the former secretary of the Academy, as one of the most ardent enemies of the shameful brigandage, which for two centuries depopulated and corrupted the African continent.

At the death of Louis XV the public voice called Turgot to the ministry. First the marine was confided to him; a month after (August 24, 1774), the finances. In his new and brilliant position Turgot did not forget the intimate confidant of his economical and philosophical thoughts; he appointed Condorcet comptroller of currency. Condorcet accepted this favor in terms worthy to be recorded.

"It is said in a certain quarter that you are very generous with the public funds when you desire to oblige your friends. I should be sorry to give these foolish words any appearance of foundation. I pray you therefore do nothing for me in the way of remuneration just now. Although not rich, I am not pressed. Let me fill the place; trust me with some important work; wait until my efforts have truly deserved a reward."

Turgot during his ministry conceived, in 1775, a general plan for the interior navigation of the kingdom. This plan embraced a vast system of works for the improvement of the small as well as the large rivers, and for the excavation of canals to unite the natural ways of communication. The celebrated minister, in this important matter, had to defend himself equally from the lovers of display, from those who seeing certain rivers separated on the map by only a little white paper, draw lines from one to the other and call these meaningless scratches their plans; from those, finally, who do not know how to gauge the power of running water, nor how to calculate its effects. Therefore he hastened to attach to the administration three geometers of the Academy of Sciences, d'Alembert, Condorcet, and Bossut. Their mission was to examine plans and to supply any hydrographic information that might be required.

These operations, undertaken on so grand a scale, were stopped by Turgot's pecuniary inability to pursue them. Notwithstanding their short continuance they have left enduring results, although perhaps in more than one instance the counsel, contained in a memoir of Condorcet, was not sufficiently regarded: "Trust only such men who, could they join the Loire to the Yellow River of China, would feel no vanity on that account, but consider that a little zeal and some knowledge was all that had been necessary to accomplish the work."

The following extract from a letter of d'Alembert to Lagrange will appropriately end the brief notice just given of the works executed by the three geometers, the friends of Turgot:

"It will be told you that I am director of the canals of navigation with a salary of 6,000 francs. This is not true. We, Condorcet, Bossut, and myself have undertaken, through friendship for M. Turgot, to give him our advice in regard to these canals, but we have refused the salary offered to us by the comptroller of the finances."

When Turgot, as minister, wished to carry out the reforms he had conceived as simple citizen; when the comptroller-general found himself assailed by the cupidity of courtiers, the powers of parliament, and the generally conservative spirit of routine, which when great changes were to be made threw doubt upon the wisdom of his plans, Condorcet did not remain a mere spectator of the struggle; he on the contrary, entered into it with the utmost ardor; to a refutation of the work of Necker against the free traffic in grain, he especially devoted his pen, and for the first time he resorts to irony in the assumed *Letter of a laborer of Picardy to M. Necker, prohibitionist.* Voltaire writes thus to our confrère August 7, 1775:

"Ah, what a good thing, what a reasonable thing, and even what a beautiful thing is that *Letter to the prohibitionist;* it must attract all enlightened minds, although there are few such left in Paris, by its good sense and taste." I would not dare to say that good sense and good taste had deserted the capital, but I know that the witty *Letter to the prohibitionist* received little notice, and that Condorcet was obliged to publish a new refutation, more detailed, more methodical, and more complete, of the work of the celebrated and rich banker of Geneva. This second article was modestly entitled, *Reflexions upon the commerce in grain.* The author in it considers successively how these cereals are produced, how the difference sometimes occurring between the harvests of one place and another can be alleviated, and the regulation effected in proportion to wages. He treats also of the mean price and of its influence, and of the equalization of prices; of the effects of unbounded liberty in commerce, and the political advantages of such liberty. Condorcet then examines the prohibitions, both in a general way and in their relations to the rights of property and legislation. Descending, finally, from these abstractions to questions more personal, without mentioning names, he inquires how the authors of the prohibitory measures acquired popularity; he seeks for the origin of the prejudices of the people, and completes his work by some critical reflections, touching certain prohibitory laws, and the obstacles opposed to the good that liberty could produce.

All the aspects of a very difficult problem are frankly considered in a severe and simple style. The work is not a mere pamphlet; it extends to more than two hundred printed pages. Its publication excited general opposition among the numerous partisans of Necker. Writers of the highest rank became from the time of its appearance the implacable enemies of Condorcet. The Academy of Sciences and the French Academy were unpleasantly affected for many years by the consequences of the discords it produced.

With the mind free from prejudice I have asked myself if, under the circumstances, our confrère overstepped the bounds of proper criticism. I suppose no one will contest his right, which he used, conscientiously, to call the work of Necker a mere translation of the celebrated dialogues of the Abbé Galiani into prosy and pompous language, or to refer in this connection to the Greek statue, graceful and beautiful, which an emperor caused to be gilded and so ruined its beauty; but this aside, in going over the work of the former secretary of the Academy I find only one note that could have excited the anger of the warmest partisans of Necker. This note mentions a certain nobleman, designated, however, only by his initials, who had made a bad translation of Tibullus. The friends of Condorcet, uneasy lest the criticism they foresaw would trouble him, endeavored to console him. "Do not fear for my reputation as an author," he said to them; "I have just taken a better cook."

Such in substance was the terrible epigram which disturbed the court and the city, which brought discord even into the bosom of the two Academies, and which endangered the liberty of our confrère. I was disposed to blame Condorcet. It seemed to me that his hostile attitude was assumed on insufficient grounds; that Necker and his adherents had not used in regard to him or Turgot injurious language, but I was mistaken.

Buffon wrote to the celebrated banker "I do not understand this *hospital jargon*—these beggars whom we call economists." Necker accused the same writers "of seeking to deceive others, and of imposing even upon themselves." He described them as imbeciles, and even forgot his dignity so far as to call them ferocious beasts.

It is for the reader to decide whether any one has a right to complain who, after using a dagger upon his adversary, received in return only the prick of a pin.

I have told how Condorcet entered into the administration of the currency; his manner of leaving this important post was not less noble. As soon as Necker became comptroller-general of the finances, our confrère wrote to M. de Maurepas, "I have pronounced my opinion too positively of the works of Necker and of his character to retain any place which depends upon his disposal. I should dislike to be dismissed, but still more to be retained in office, by a man of whom I have spoken as my conscience has forced me to speak of M. Necker. Permit me to place in your hands my resignation."

Condorcet did not so exhaust his ire against contemporary heresies, as to have none left to combat the errors of ancient writers, even the most illustrious.

No one is ignorant that Pascal was occupied a few years before his death with a work intended as a defense of the truth of the Christian religion. This work was not finished. D'Arnaud and Nicole published extracts from it under the title of *Pascal's Thoughts upon Religion and upon other Subjects.* Condorcet, suspecting that this work had been brought to light in the interests of a party and of certain mystical systems rather than for the reputation of the author, procured, in the beginning of 1776, a complete copy of the manuscripts of Pascal, obtained from them various passages that the saints of Port-Royal, with their Jansenistic consciences, felt obliged to suppress, arranged them methodically, and composed of the whole an octavo volume of 507 pages, copies of which were sent to all the friends of the author, but which was not offered for sale. Frankness compels me to say that the compiler of this new edition of *Thoughts* indulges, as did Arnaud, although in an entirely different spirit, in systematic suppressions. We hasten to add, however, that we have found a eulogy of Pascal by Condorcet, in which the great geometer, the ingenious physicist, the profound thinker, the eloquent writer is fully appreciated, and, with the most noble justice and impartiality, Condorcet adds critical commentaries to several of the *Thoughts* of Pascal. This audacity, in which Voltaire himself had already set him an example, excited great indignation; it was considered a sacrilege. To-day the public would have been more indulgent. The admiration, amounting to veneration, of that time is out of fashion now, and, if I do not deceive myself, the tendency is in the opposite extreme. We no longer think of asking, is such a criticism of a celebrated author irreverent, but is it just. Considered, then, from our present point of view, the remarks of Condorcet may be approved almost without exception.

When the author of the *Thoughts*, pushing misanthropy to its utmost limits, stated that if men were cognizant of all that was said by one of another there would be not four friends in the world; I like to find the commentator protesting against this antisocial decision and blaming Pascal for giving such a strange idea of his friends.

When, in his ardent war against man's love of his own greatness, Pascal insinuates that our actions, even those apparently most disinterested, are always tinged with feelings of self-love, by the hope of publicity and applause which follows in its train; I read with delight, in a note of the commentator, this touching anecdote borrowed from our *Annales Maritimes*, and which contradicts the melancholy declaration of Pascal: "The vessel which contained the Chevalier de Lordat was wrecked and about to sink in view of the shores of France. The chevalier did not know how to swim; a soldier, an excellent swimmer, offered, if he would spring with him into the sea and would cling to his arm, to save him if possible. After swimming for a long time the strength of the soldier became exhausted. M. de Lordat perceiving this endeavored to encourage him, but the soldier at last declared that they must both perish. 'And if you were alone?' 'Perhaps I might still be able to save myself.' The chevalier let go his arm, and sank to the bottom of the sea."

Voltaire caused the book to be reprinted at his own expense in 1778. Hitherto it had received only a partial publicity. Voltaire, let it be said in his praise, thus became the editor and the commentator of the young secretary of the Academy of Sciences. This was for Condorcet a very great honor, and, moreover, deserved, on account of the merit of the work. Am I mistaken, however, in supposing that in this action of Voltaire with the sincere homage of the author of the *Dictionnaire philosophique* was mingled some animosity against the Jansenistic writer; that the author of the *Henriade*, of *Mérope*, and of so many admirable smaller poems, saw with a secret joy the infallibility of that man attacked who, placed in the first rank among prose writers, had dared to say, even after the publication of the *Cid* and of *Cinna*, that "all poetry was in fact *only a jargon*"? A certain amount of anger must have influenced the pen of the illustrious poet when, in his appreciation of a work in which the praise is always so frank and the criticism so moderate, he says to Condorcet, "You have shown us the inside of the head of Serapis, and we find in it rats and spider-webs."

In Condorcet's edition of Pascal we find this thought oft repeated: "Speaking according to the natural light of reason, if there is a God, He is infinitely incomprehensible, since having no beginning and no end, he can have no connection with us. We are then capable of knowing neither what he is nor *if he is*." The portion of the phrase *nor if he is* is not found in the old editions of the works of the illustrious thinker. Condorcet seemed, therefore, to have been guilty of an inexcusable interpolation of the text. The suspicion that he had committed this grave offense gained weight when, in 1803, M. Renouard, the celebrated bibliographer, declared (these are his own words) that "an obstinate search through the manuscripts of Pascal, preserved in the Royal Library, had failed to discover the three contested words."

The fact stated by M. Renouard must at the time have caused some uncertainty even in the minds of those who had never doubted the perfect rectitude of Condorcet. In this day the testimony of this celebrated librarian is worth nothing, since we know that in 1812 M. Renouard frankly acknowledged that the fourth page of the almost illegible manuscript of the library did in fact contain the thought of Pascal as Condorcet had published it. To cut short all gratuitous supposition in regard to this supposed alteration of the precious manuscript, I will add that the contested words are found in an edition of the *Thoughts* anterior to that of Condorcet, and published by Father Desmolets.

I cannot allow this opportunity to escape of justifying Condorcet from an imputation of the same nature, shocking alike from its violence and its levity. Read, gentlemen, the article upon *Vauvenargues*, in the work of La Harpe, entitled *Philosophy of the XVIIth century*. The irascible critic first recalls to memory the eloquent prayer which terminates the book of this moralist, and immediately after accuses Condorcet of having affirmed, with anti-religious views, that the prayer was not by Vauvenargues. It is in the *Commentary upon the works of Voltaire*, says La Harpe, that this *philosophical falsehood* is to be found.

Never, assuredly, was reproach of such gravity expressed in plainer terms. What must be my reply? The most positive denial of the charge: Condorcet never pretended that the prayer was not by Vauvenargues; he said very clearly, on the contrary, that it was. Can there be possibly such a thing as an anti-philosophical falsehood?

At the end of one of his best eulogies, that of Franklin, our confrère blames very severely those persons who regulate their conduct upon the maxim, old but of low morality, *the end justifies the means*, and denounces indignantly all success obtained by falsehood or perfidy. The actions of Condorcet were in accordance with these noble sentiments; his life was one long contest, but he never had recourse to arms obtained through disloyalty and untruth.

Formerly every nomination to the French Academy was an event, especially when men of the court were to be admitted. Condorcet took part more than once in the debates these occasions produced, but never allowed any consideration for rank to outweigh claims founded on true literary merit. When Saint-Lambert requested him to inform Turgot that the French Academy desired to give him a mark of its esteem and to nominate him in the place of the Duke of Saint Aignan, Condorcet, although he desired greatly that his friend should become a member of the Academy, very plainly advised him to decline the nomination if his acceptance should cause any one making literature a profession to be rejected by the court, which was at that time always consulted before the election of a member. Our confrère thus manifested his true esteem and profound respect for the love of letters.

His counsel was addressed to one worthy to appreciate it. Turgot did even more than his friend had advised. Here is his answer: "Thank for me M. de Saint-Lambert. At this time it would not be suitable for me to draw upon me the eyes of the public for any other purposes than the affairs of my ministry. I think there should be an effort made to elect La Harpe. If this does not succeed, why should not the Academy take the Abbé Barthélemy? And there is M. Chabanon; not to consider his claims to the nomination seems to me to be treating him very severely. He is not, whatever may be said, without talent. They were not always so particular."

Perhaps in our time affairs are conducted as nobly; but even if this is so, I do not regret these citations, for they prove that our fathers were at least as worthy as ourselves.

Condorcet entered into competition in 1782 for the place of Saurin in the French Academy, and carried the nomination by only one vote over Bailly, the other candidate. The contest over the election was very warm, d'Alembert representing one side and Buffon the other. La Harpe gives some idea of the zeal manifested since he tells us that when the issue of the votes was declared d'Alembert cried out before the whole Academy: "I am more pleased to have gained this victory than I would be if I had found the quadrature of the circle."

The disfavor that this nomination drew upon Condorcet (the expression of this feeling is found in most of the writings of the time) is to me inexplicable. Were the literary claims of Bailly to the nomination so indisputably superior to those of Condorcet that the latter could not honestly have received the preference? "Should speculation," d'Alembert maliciously remarks, "in regard to an ancient people, about whom every thing is known except their name and place of abode, overbalance the ingenious, learned, and often elegant descriptions of men of our time?"

In any case, supposing Condorcet was mistaken in his claims to an Academic chair, the illusion was a very natural one. Thus in the unpublished *Correspondence* of Voltaire, I have so often quoted, I read, under the date of 1771: "You should do us the honor of belonging to the Academy. We have need of men who think as you do." Is this said in mere politeness, and not seriously?

I pass over an interval of five years, and on the 26th of February, 1776, find in another letter of the great poet: "Belong to our Academy; your name and your eloquence will have some effect upon the set of hired assassins established in Paris." The same desire is repeated with variations in several letters of the month of March. That of the 16th contains this passage: "I repeat to you that if you do not this time do me the honor of joining us, I shall go and pass the rest of my *youth* at the Academy of Berlin or that of St. Petersburg." The old man becomes afterward still more pressing: "I wish you would promise me," he writes on the 9th of April, 1776, "for my comfort, that you will take my place in the Academy and aid our assembly with your words, as you have supported it with deeds. Be received by M. d'Alembert, and I will feel greater confidence that all will be well."

Voltaire the sceptic doubts everything except the merit, the attachment, and the gratitude, of our confrère.

We are now at the commencement of 1776. At the close of the year following, the 24th of November, 1777, the author of *Mérope* wrote again to our former secretary: "I shall always be tenderly attached as long as I live to him who forms the glory of the Academy of Sciences, and I hope he will some day do the same for the French Academy. Since the history of literature makes regretful mention of many candidates who entered the Academy only after soliciting long for the honor, I may be permitted to show one man of letters who became an academician only after he had been long solicited."

Condorcet Testamentary Executor of d'Alembert.—His Marriage with Mademoiselle de Grouchy.

The ordinary, the regular course of things in this world brings some days of mourning, of tears, and of deep sorrow even into the least troubled lives. Condorcet experienced this in 1783. That year, on the 29th of October, death robbed him of his friend, the illustrious geometer, who under all circumstances had been his guide, his support, his foster father.

The great man, who had succumbed in the plenitude of his mathematical genius, had assumed as a rule of conduct this maxim, which will no doubt by many be considered very puritanical: "The use of the superfluous is wrong, when others are deprived of the necessary." D'Alembert acted through life upon this principle and died, therefore, without fortune. In his latter days he was not only a prey to cruel physical pain, the consequences of a dreadful malady (the stone); he suffered perhaps even more deeply from the impossibility to which he had been reduced by his constant generosity, of suitably rewarding his two faithful servants. A classical incident occurred suddenly to the memory and brought peace to the mind of the celebrated academician.

Eutamidas bequeathed to one of his friends the mission of taking care of his mother, to another of marrying his daughter; a similar testamentary request confided to Condorçet the duty of providing annually for the needs of the two servants. The mission lasted long: Condorcet placed it among the number of his first duties and fulfilled it with religious fidelity. General and Madame O'Connor have continued his example.

The arduous duties devolving upon the secretary of the Academy of Sciences, the obligation of maintaining an active correspondence with the cultivated men of all countries of the civilized world, an irresistible inclination to take part in the debates of which the social and political condition of the country was every day the object, very early decided Condorcet to give up general society. The sacrifice could not have cost him much, for in the eulogy of Courtauvaux he denounces its amusements as dissipation without pleasure, vanity without motive, idleness without repose. Outside of his scientific relations our confrère frequented only a few choice social gatherings where, in contact with the eminent men of the time, the young men learned to discuss the most exciting questions with moderation, delicacy, and modesty. It was in one of these family reunions that Condorcet met, for the first time in 1786, Mademoiselle Sophie de Grouchy, niece on her mother's side of M. M. Fréteau and Dupaty, members of parliament. Like all the rest of the world our confrère admired, first, the rare beauty, the distinguished manners, the brilliant and cultivated mind of this young person. Soon he discovered that these attractions were united to a noble character, a heart most true, an affectionate and benevolent nature. Condorcet then became strongly attached to the young lady, and demanded her in marriage. Our confrère was at this time forty three years of age, and had only a moderate income; but such was the violence of his passion that he made no written agreement, but only a verbal contract with his future parents for the dowry of his wife. This, gentlemen, is very far from the calculating, cold disposition which has been attributed to Condorcet, a character drawn from that of certain of his friends for whom he professed an unlimited admiration, and with whom he was wrongfully supposed to be in sympathy in every way and upon all subjects.

At that time, with very few exceptions, savans, mathematicians especially, were regarded by the world as beings of a separate order of nature. They should, it was thought, like ecclesiastics, be interdicted the concert, the ball, the play. A geometer who married was considered as infringing upon a principle of right. Celibacy seemed the obligatory condition of whoever devoted himself to the sublime theories of analysis. Was this mistake altogether on the side of the public? Were not the geometers themselves instrumental in promoting such views? Listen, gentlemen, and judge for yourselves.

D'Alembert receives indirectly from Berlin the information that Lagrange is about to give his name to one of his young relatives. He is somewhat astonished that a friend with whom he is in correspondence has told him nothing of such intentions. This does not, however, prevent him from mentioning the matter in a bantering way. "I learn," he writes on the 21st of September, 1767, "that you have made what we philosophers call the perilous leap. * * * A great mathematician ought above all things to know how to calculate his own happiness. I do not doubt, then, that, having made this calculation, you find marriage to be the solution." Lagrange responds in this singular manner: "I do not know whether I have calculated well or ill, or rather whether I have calculated at all, * * * or I may be like Leibnitz, who, by force of reflection, never could come to a determination. I must confess to you that I have never had a taste for marriage, * * * but circumstances have decided me * * * to engage one of my relatives * * * to come and take care of me and all that concerns me. If I have not informed you of this it was because it seemed to me a matter of so little importance in itself that it was not worth while to trouble you with it."

The marriage of Condorcet would also have appeared to me a matter of no importance, and not worth mentioning in this biography, if it had been, as d'Alembert suggests, the result of a calculation. On the contrary, without calculation of any kind, but solely in obedience to the inspirations of a feeling heart, Condorcet had the happiness to find a companion worthy of him. The beauty, grace, and wit of Madame de Condorcet formed a sort of miracle. The most decided adversaries of marriage among the savans, especially the mother of the Duke de La Rochefoucauld, the respected Duchess d'Anville, yielded so far as to say to our former secretary, "We pardon you."

CONDORCET AS A POLITICIAN—A MEMBER OF THE MUNICIPALITY OF PARIS—COMMISSIONER OF THE NATIONAL TREASURY—MEMBER OF THE LEGISLATIVE ASSEMBLY—MEMBER OF THE CONVENTION—HIS VOTE IN THE TRIAL OF LOUIS XVI.

We now enter into a series of considerations and events of a totally different nature from those which have hitherto occupied our attention.

Condorcet is about to take part in the most important events of our revolution.

If it is true, as a celebrated diplomatist has said, that speech often serves to disguise thought, we may add that under certain circumstances, silence is a very unequivocal means of expression. Suppose, for example, that I say nothing of the political life of Condorcet, who would believe that it was not made up of blamable deeds? Heaven forbid that I should voluntarily give reason for a conjecture so contrary to the truth, that I should become the tacit auxiliary of the many scurrilous writers who attacked with a sort of fury the former secretary of this Academy. Every one, in his own cause, has assuredly the right to meet with silent contempt the abuse of adversaries he may consider beneath notice; but this alone is not sufficient for him whose mission it is to defend an honorable citizen, an illustrious brother, the victim of the basest calumnies.

In the society of Turgot our brother became a man of progress not only in social but political economy. Placed near the seat of power for eighteen months, he saw in their most secret details the play of the worm-eaten wheels of the ancient monarchy. Condorcet comprehended their insufficiency, and, although changes were to him personally prejudicial, he never allowed an opportunity to escape of urging their necessity. I do not know whether such noble disinterestedness is common at present; it was not at least in the times of which I speak. Witness, for instance, the naive question addressed to Condorcet by a *Fermier général*, enjoying an income of two or three thousand livres: "Why innovate? Are we not well off?"

No, assuredly; honest men were not common in the days when Turgot, the minister, said to our confrère: "You do very wrong to write to me by the post; you may injure yourself and your friends. Write to me, I pray you, only by special opportunity, or by my couriers."

The "*black* cabinet" opening letters addressed to a minister! Is anything further necessary to show the character of the times? In order to understand the ameliorations France desired, Condorcet did not need to consult the instructions that in 1789 the members of the constituent assembly brought from all parts of the kingdom. His programme of action, perfectly in accord with the best conceived resolutions of the provincial assemblies, was written out in advance. He had found its elements in an earnest and philosophical study of the natural rights, of which a society well organized will not, and cannot, deprive the most humble citizen. The ideas, the wishes, the hopes of our confrère form the chief interest of the *Life of Turgot*, published in 1786. To-day, even, when most of the privileges claimed by Condorcet in the name of reason and humanity have been definitely acquired, publicists may still learn much from reading the work of our confrère. They will see in it, with astonishment perhaps, but also with full conviction, that the vague principle of the greatest good of society has often been a fruitful source of injurious laws, while they will always secure regulations and prescriptions the necessity and the justice of which must be acknowledged by all, when intent only upon securing to the public, the enjoyment of their natural rights.

I do not know whether, in the present state of opinion, my appreciation of the work of the illustrious philosopher will be generally approved. I may at least assert that every loyal man must experience one sentiment, that of respect, in witnessing with what vigor, since the year 1786, the Marquis Caritat de Condorcet attacked the privileges of the nobility.

Condorcet after much study had written, at the dictation of his conscience, the imperative mandate he was prepared to issue, if circumstances ever gave him the political power. I perceive in this programme many points which have never been decided according to his views, either in fact by our assemblies, or in theory by publicists in general.

Condorcet did not wish two chambers; but that which he demanded, particularly that which seemed to him the base of a well considered social organization, was a legal and periodical means of revising the constitution, so as to adjust peacefully the disaffection of parties.

The combination of two chambers seemed to him a useless complication, in some cases leading to results evidently contrary to the wish of the majority. He believed "that in the deliberations of a single assembly are found all the elements necessary to secure to legislative enactments all the consideration and the maturity of judgment required for their justice and wisdom." Franklin, a decided partisan of a single chamber, confirmed Condorcet in his views. The eulogy of this great man furnished later to our brother a natural occasion for the development of his opinion, which he seized with avidity. Also, in this same eulogy the learned secretary proclaimed as an inevitable source of evils and disorder any constitution considered unchangable, any constitution which did not provide means for modifying such of its regulations as might cease to be in harmony with the state of society.

With Condorcet as simple citizen or as member of our assemblies, the political man is concentrated into these two ideas,—natural rights, rights imprescriptible which no law can infringe without injustice, and political constitutions containing in themselves a legal means for the reform of abuses. This was his evangel. Whenever his favorite principles are combatted or even only questioned he hastens to their defense. His language then becomes animated, passionate. Read, for example, this passage from a letter he wrote on the 30th of August, 1789, at the time when the constituent assembly had just rejected the proposition made by Mathieu de Montmorency to secure by means of an express proviso the possibility of future improvements in the fundamental compact:

"If our legislators aspire to work for eternity, they ought to bring down a constitution from the skies. To Heaven has alone been accorded the right to give immutable laws. We have lost the art of working miracles and of making oracles speak. The Pythoness of Delphos and the thunders of Sinai have for ages been reduced to silence. The legislators of to-day are but men, who can give to men—their equals, only laws as fleeting as themselves."

The first functions of a political order exercised by Condorcet were those of member of the municipality of Paris. In this capacity he was the author of the celebrated address presented by the city to the constituent assembly, to demand the reform of a very important law, the law which had just been passed, and which made the right of citizenship and the other political rights to depend upon the quota of its contributions. The remonstrances of Condorcet and his colleagues were not without effect.

Condorcet was still exercising his municipal functions when he demanded, this time in his own name, that the King should always select his ministers from a list of those qualified, the formation of which should be one of the principal prerogatives of the representative assembly. Would such a process prevent a bad selection? I certainly hesitate to affirm it. I am certain that the list of candidates would be very difficult to make, and would compel laborious investigation.

Condorcet was much more in sympathy with the actual world when he pointed out the dangers attached to the creation of assignats, when he indicated almost infallible means for obviating all the inconveniences of this paper money.

The flight of the King and the circumstances of his return threw discouragement over the minds of the most decided partisans of the monarchial system. La Rochefoucauld, Dupont de Nemours, and others, even held meetings where the means of establishing a republic without too great violence were very seriously discussed. This project was afterwards completely abandoned. Condorcet, an active member of these extra-parliamentary debates, did not consider himself bound by the decisions of the majority to keep secret the opinions he had given; he allowed his speeches to be read at the *Cercle Social*, and this assembly caused them to be printed. From this time dates the unhappy rupture which suddenly, and without hope of restoration, separated him from his best, his oldest friends, and in particular from La Rochefoucauld.

When the questions which the arrest of Varennes inevitably raised reached the national tribune, Condorcet, although he was not a member of the assembly, became in it an object of attacks and of violent personal abuse. The illustrious publicist admitted without hesitation that his opinions might be in part erroneous; but considering the character of those who made such fierce war against him, their disdain excited his surprise. "Was it excessively ridiculous," he asked himself (I copy here a passage from a manuscript), "that a geometer of forty-eight years, who for nearly a third of a century had studied political science, who was the first perhaps to apply mathematical calculation to this science, should be permitted to have a personal opinion upon questions debated in the constituent assembly?" Parliamentary customs were not yet fully developed. Condorcet could not divine that a day would come when, in order to be allowed to speak upon all subjects, it should be imperatively necessary to have made no special study of any.

In 1791, after quitting the municipality of Paris, Condorcet became one of the six commissioners of the national treasury. The memoirs which he published at this period would occupy a prominent place in the eulogy of an author less fruitful and less celebrated. Embarrassed by want of time and abundance of material, I cannot even mention their titles.

Condorcet, having renounced towards the latter months of 1791 the place of commissioner of the treasury, went to Paris as candidate for the legislative assembly. Never was there a candidate more violently opposed, never did the venal press indulge in more libels. It was my duty to investigate and weigh these emanations of party spirit; but I should weary my audience if I attempted to give an analysis of them. I must confess that, amidst the torrent of calumnies and absurd accusations, there was one assertion made in such a clear and categorical manner that in the absence of an equally formal denial, which I could nowhere find, the wrong attributed to our confrère made me really uneasy. Thanks to the respectable M. Cardot, for a long time Condorcet's secretary, all clouds of doubt have disappeared. Condorcet, said his accuser, visited the court nightly, and especially *Monsieur*, brother to the King, even at the time when he was attacking them in his writings, and then follow the names of persons who could testify to these clandestine communications. "Yes! yes!" cried the chief clerk of our secretary, when I consulted him, "I remember that grave imputation, but I remember also that it was proved that the mysterious nocturnal visitor was not Condorcet, but Count d'Orsay, master of the household of *Monsieur*." You see, gentlemen, in times of political animosity, how easily the reputation of the most honest man may be compromised.

Hardly had he been nominated to the legislative assembly when he became one of its secretaries. Later he was raised to its presidency. Timidity, great feebleness of the lungs, the impossibility of preserving his *sang-froid* and presence of mind amidst the noise, agitation, and tumultuous movements of a large concourse kept him away from the tribune, which he mounted only on rare occasions; but whenever the assembly wished to make a serious and impressive address to the French people, the army, to interior factions, or foreign nations, it was always Condorcet who became its official organ.

During his legislative career Condorcet gave especial attention to the organization of public instruction. The fruit of his reflections upon this important subject are recorded in five memoirs, published in the

Bibliothèque de l'homme public, and in the exposition of his ideas on the law which he presented later to the legislative assembly.

Condorcet entirely abandoned the beaten tracks. He has submitted to very careful examination even those institutions and methods which by their universality seemed beyond question. He threw new light upon the subject by considering it from points of view well worthy the attention of the legislator, as an enlightened friend of his country, on account of their novelty and importance. Whatever may be the opinion of the matter, the impartial reader cannot fail to render homage to the clearness of view, the largeness of conception manifested by Condorcet in the various parts of his work.

Here, according to date, should be mentioned a motion of Condorcet I cannot fail to notice. The compass of this motion I am sure has been seriously exaggerated. This assertion has not been made without mature reflection, for it places me in direct opposition to one of the most illustrious men of our time. It requires considerable confidence in the power of truth to dare oppose alone an error, without doubt involuntary, but supported by the prestige of the highest eloquence.

Parliamentary history offers nothing more touching, more curious, than the analysis of the session of the constituent assembly of the 19th of June, 1790. The day when Alexandre Lameth solicited the removal of four chained figures, then to be seen in the Place des Victoires at the feet of the statue of Louis XIV, an obscure deputy of Rouergue, M. Lambel, cried from his seat: "To-day is the tomb of vanity. I demand that henceforth it shall be forbidden any one to take the titles of duke, marquis, count, baron," &c. Charles Lameth supported the proposition of his colleague; he desired that in the future no one should be called noble. Lafayette considered the two demands so evidently necessary, that he thought it superfluous to support them by many remarks. Alex. de Noailles agreed with the latter, but considered the suppression of liveried servants equally urgent. M. de Saint-Fargeau proposed that no one should bear any other name than that of his family, and set the example by immediately signing his own motion,—"Michel Louis le Pelletier." Lastly, Matheu de Montmorency insisted that armorial bearings, heraldry, which were among the most apparent remains of the feudal system, must not be spared, and demanded their immediate abolition. These propositions were presented, discussed, adopted, almost in as short a time as I have taken to give an account of them. In all this our confrère did not take an active part, for the very simple reason that he was not a member of the constituent assembly. If it was a fault to rupture so suddenly all connection between the past and the present, Condorcet, at least, cannot be blamed for it. We have, in fact, since learned, through the memoirs of Lafayette, that upon the question of the abolition of heraldry, our learned philosopher did not agree with Montmorency. It seemed to him, on the contrary, more in accordance with the true principles of liberty, rather than to suppress armorial bearings, to permit every one, the plebeian, the artisan, the beggar, as well as the noble, to assume them if so inclined.

The law for the abolition of titles of nobility contained nothing specific concerning the penalties attached to its infringement. Such a law, a law without proper sanction, is never observed in any country, and soon falls into disuse. It was, no doubt, to recall to mind its existence, that on the anniversary of the day on which it was passed by the constituent assembly, the 19th of June, 1792, the legislative assembly at Paris caused to be burned a large quantity of brevets or diplomas of dukes, marquises, vidames, &c. The flame was still burning at the foot of the statue of Louis XIV; the last contribution to it was, perhaps, the original title of the Marquis Caritat de Condorcet, when the heirs of this family demanded of the national tribune that the same measure should be extended to all France. The proposition was unanimously adopted.

This proposition has been textually inserted in the *Moniteur*.* It evidently relates only to titles of nobility. A decided partisan for unity in the legislative power, Condorcet hoped to defeat his adversaries (who still meditated the creation of two chambers,) by the destruction of certain parchments which they seemed inclined to consult when composing the personnel of their senate. The artifice was perhaps shabby, puerile. Still it does not authorize an illustrious writer, the honor of our literature, to present it as the immediate cause of the abandonment of certain historical works, because these works had ceased entirely a year before, in 1791. It still less authorizes a serious journal, and of recent date, to tell us that the new Omar, Condorcet, caused to be burned the extensive records of the learned associations, for these records were not burned; the proposition can be read as Condorcet made it, and it refers absolutely only to titles of nobility; for (and this moral argument is in my eyes even stronger than positive facts and dates) there never could have existed a French chamber, whether created by a monarch or by the populace, with elections of any order, which would have sanctioned by a unanimous vote the barbarous, anti-literary, anti-historic, anti-national act, so lightly attributed to the former secretary of the Academy.

It is at about this epoch, and not after the condemnation of Louis XVI, as has erroneously been supposed, that, by the formal order of Catherine and Frederick William, the name of Condorcet was effaced from the list of members composing the academies of St. Petersburg and of Berlin. Notwithstanding all my efforts, I have not been able to discover whether these two acts of disapproval distressed to any great degree our secretary. Not a line, not a single word of his numerous manuscripts and printed works refers to this event. Condorcet imagined perhaps, that as the imperial and royal confirmations added little to the

* See the discourse of Condorcet, of the 19th of June, 1792.

actual value of the literary titles he could regard the withdrawal of these confirmations as a fact little worth his attention.

Condorcet had seen arise in the legislative assembly the personal dissensions which, growing in bitterness, threatened to imbrue the convention in blood, and bring the country to the verge of ruin. He was never willing to take part in these combats when they seemed to center upon individual names. All his tendencies were to moderate rather than to excite these broils. Several times he addressed to the ears of the factions these words, full of wisdom: "Think a little less of yourselves and a little more of the public good."

In times of revolutionary agitations, he who is governed by principle alone is soon considered weak by all parties. Of this Condorcet was an example. Witness on the one hand this passage from Madame Roland: "We may say of the intelligence of Condorcet in relation to his person, it is a fine essence pervading cotton." On the other hand, the electoral corps of Paris, then completely Jacobin, when called upon to nominate its representatives to the convention, withdrew from Condorcet the mandate which had made him a member of the legislative assembly.

A little later in this same convention, for which five departments, in default of that of the Seine, had nominated Condorcet, we will see that it is possible to be both cotton for personal questions and bronze for questions of principle.

Condorcet acted as one of the judges of Louis XVI I know that, by a sort of tacit consent, it is customary to consider this period of our history as ground too hot to dwell upon with prudence. I think such reserve objectionable. The mystery in which the events of the time are enveloped tends to promote the belief that, to the eternal shame of our national character, not a patriotic feeling, not an act of courage, not an elevated idea, not a sentiment of justice, was brought to light during the long period of the painful drama. .

The large portion of the public to whom the Moniteur and other official sources of information are interdicted, on account of their high price or their rarity, are acquainted with this part of our annals only through a few barbarous phrases, several of which have been repeated from generation to generation, but are none the less contrary to the truth. The overcaution, which under such circumstances would prevent the historian from attributing to each person his real part of the responsibility, is, in my opinion, inexcusable. I will, therefore, tell you faithfully and without reticence what was Condorcet's conduct during the celebrated trial.

Could the King be tried? His inviolability: was it not absolute according to the terms of the constitution? Liberty: was it possible in a country where positive law ceased to be the rule of judgment? Would it not be violating an eternal axiom, founded upon humanity and upon reason, to prosecute actions which no anterior law had stamped as derelict or criminal? In strict justice, should not the mode of judgment have been regulated before the time of the offense or crime? Was it to be hoped that a fallen sovereign might find impartial judges among those he once called his subjects? If Louis XVI had not counted upon absolute inviolability, are we sure that he would have accepted the crown?

Behold the series of questions, assuredly very natural, which Condorcet presented to the tribune of the convention, and which he submitted to a severe discussion before the commencement of the trial of Louis XVI. I ought to enumerate them if only to show to what extent they may deceive themselves to whom the history of our revolution is known only by a sort of oral tradition, which represents all the members of the convention as tigers, thirsty for blood, taking no care to cover their fury with even the appearance of right and legality. Condorcet admitted that the King was inviolable, that the constitutional compact justified all the acts of power which were delegated to him. He did not believe that the same rule should be extended to personal derelictions, if they were without necessary connection with the functions of royalty. The most perfect codes, said Condorcet, contain defects. That of Solon, for example, makes no mention of the parricide. The monster guilty of such a crime, should he therefore remain unpunished? No, certainly; to him was applied the penalty of the murderer.

In admitting condemnations by analogy, Condorcet desired at least that the tribunal, constituted with unusual prerogatives, should be based upon dispositions favorable to the accused; he desired the right of recusation more extended; the necessity of a larger majority for the condemnation, &c. According to his views, the judgment of the King should have been confided to a special jury, chosen from the whole country by means of electoral colleges.

The right to punish the King did not seem to our confrère so incontestable as the right to judge him. The idea of a sentence in some sort moral might seem, perhaps, strange; Condorcet saw in it the occasion of showing to Europe, by a legal discussion, that the change of the French constitution had not been the effect of the simple caprice of some individuals.

After having developed the opinions, true, false, or questionable, that have just been presented to you, Condorcet declared, with no less sincerity, that, without violating the first principles of jurisprudence, the convention could not judge the King. A legislative judiciary was in his eyes a veritable chimera. Such an assembly, at once legislator, impeacher, and judge, seemed to him a monstrosity, an example the most dangerous. In all times, he said, and in all countries, the judge has been considered lawfully reprehensible who in advance manifests any opinion of the culpability or the innocence of the accused. In fact, justice cannot be expected from men who, forced to renounce an opinion publicly expressed, must consequently incur at the least the reproach of fickleness. Now, said Condorcet, in a solemn declaration addressed to the Swiss nation, the convention has already pronounced upon the culpability of the King. Condorcet as to the rest demanded that in the case of condemnation, the right should be reserved of mitigating the punishment. "To pardon the King," said he, "may become an act of prudence; to conserve the power to do so is an act of wisdom."

It is in the same discourse that I read the words, whose beauty are enhanced by the solemn circumstances of the speaker:

"I believe the punishment by death unjust. * * * The abolition of the death penalty would be one of the most efficacious means of elevating the human species by assisting to destroy the inclination towards ferocity, which has long dishonored it. * * * Punishments which allow correction and repentance, are alone suitable for the regeneration of the race."

The convention, scorning all the scruples Condorcet had raised, constituted itself a sovereign tribunal for the trial of Louis XVI. Our brother did not decline to take part. Was this one of those cases in the body politic, when the minority must blindly submit to the yoke of the majority? The most criminal of usurpations is, without contradiction, that of the judicial power; it wounds both the intelligence and the heart. On such a subject, could the testimony of the conscience be placed in the balance against the material result of the ballot? Let us not always carry severity to the extreme; let us remember that in the open sea, in the midst of the storm, even the most intrepid sailor is sometimes seized with dizziness the timid landsman safe on shore has never experienced. It would certainly have been more Roman to have refused the function of judge; it was more human, according to the ideas of Condorcet, to accept it. Condorcet refused to vote for the punishment of death. Any other penalty he considered could be awarded, and he demanded an appeal to the people.

DISCUSSION OF THE CONSTITUTION OF THE SECOND YEAR.—CONDORCET AN OUTLAW—HIS RETREAT WITH MADAME VERNET—HIS SKETCH OF A HISTORY OF THE PROGRESS OF THE HUMAN MIND.—FLIGHT OF CONDORCET—HIS DEATH.

Of all the writings of Condorcet none exercised so fatal an influence upon his destiny as the plan for the constitution for the second year.

In the midst of the incomparable efforts made by the convention to repulse the armed enemy, to suppress the civil war, to create financial resources, to resupply the arsenals, the political organization of the country was not forgotten; a commission composed of nine of its members was intrusted with the preparation of a new constitution. Condorcet was one of the nine. After several months of assiduous labor and of profound discussion, this commission presented, on the 15th and 16th of February, 1793, the result of its deliberation. The new plan of the constitution consisted of not less than thirteen heads, subdivided into a great number of articles. An introduction of a hundred and fifteen pages, written by Condorcet, gave in detail the motives which had decided the commission. The convention accorded to the draught of our colleague the preference over all the others presented for its consideration from other quarters, and concluded that it would without delay be publicly discussed. Violent debates excited each day by personal enmity, the bitterness of party spirit; the wearisome difficulties of the circumstances, and the incessant usurpations of the commune of Paris absorbed all the time of the sessions. Condorcet, caring only for what he considered as directly promoting the triumph, the glory, and the happiness of France, grieved to see the consideration of the constitution day by day deferred. In his impatience he demanded a limit fixed for the delay, at the expiration of which a new convention should be called. At Paris the proposed constitution received very little attention; the departments, on the contrary, received it with favor. It carried and promoted ideas which had become so powerful that it was impolitic not to take them into account. Accordingly after the events of the 31st of May and the 2d of June, the part of the convention in the ascendency considered it opportune to gratify without delay the wish of the people for the constitution so long promised the country; but it refused to take up again the plan of Condorcet. Five commissioners, appointed by the committee of the public safety, at the head of which was Hérault de Séchelles, made a new plan which the committee amended and accepted in a single session. The convention was not less expeditious. The constitution presented on the 10th of June, 1793, was decreed on the 24th of the same month. The happy shouts of the populace and the thunder of cannon announced in Paris the great event.

The constitution, according to the terms of the decree, was to be sanctioned or rejected by the primary assemblies in the short space of three days from the time of notification, and here occurred an act of Condorcet in order to appreciate the bravery of which it is necessary to go back in thought to that terrible period in our annals which followed the 31st of May.

Sieyès, in private confidence, called the work of Hérault de Séchelles a bad index of subjects. What Sieyès said in secret Condorcet dared to write to his constituents. He did more: in a letter made public, the celebrated savant openly proposed to the people not to sanction the new constitution. His reasons were many and clearly expressed:

"The integrity of the national representation," said Condorcet, "has just been destroyed by the arrest of twenty-seven Girondin members. The discussion could no longer be free. Inquisitorial censure, the pillage of printing offices, the violation of the secrets of letters, must be considered as having presented insurmountable obstacles to the manifestation of the popular sentiment. The new constitution," added Condorcet, "as it speaks of no compensation for the deputies, leads to the supposition that it is considered desirable to compose the national convention always of rich men or of those with good prospects for the future. The elections, too indirect, are a premium for intrigues and mediocrity. It is an insult to the people to suppose them incapable of making good immediate elections. To compose the executive power of twenty-four persons is to throw affairs into hopeless stagnation. A constitution which does not guarantee civil liberty is radically defective. There is in some minds a tendency toward federalism, toward the rupture of French unity, but the greatest mistake is to have rendered the means of reform illusory."

A critic so quick, so accurate, so just, moreover, could not have been welcome to the authors of the project, but what followed irritated them still more, for self-love is always the weak side of our species, even with those who call themselves statesmen.

"All that is good in the second project of a constitution is copied from the first,—which has only been perverted and corrupted by the attempt to correct and improve." Chabot denounced the letter of Condorcet to the convention in the session of the 8th of July, 1793. The ex-Capuchin called the new constitution of Hérault de Séchelles a *sublime work.* He spoke of the criticism as an *infamous* article which only villains could tolerate, and after the use of these abusive terms, adds: "Condorcet pretends that his constitution is better; that the primary assemblies ought to accept it. I propose, therefore, that he be placed under arrest, and compelled to plead his cause at the bar."

The assembly accordingly decreed without further accusation that the illustrious deputy from Aisne should be arrested and the state seal placed upon his papers.

Condorcet, although generally, but erroneously, considered a Girondist, was not among the number of the twenty-four deputies arrested on the 31st of May. On the 3d of October, 1793, however, his name is found with those of Brissot, Vergniaud, Gensonné, Valazé, in the list of the conventionals brought before the revolutionary tribunal, accused of conspiracy against the unity of the republic and condemned to death.

Condorcet, condemned as contumacious, was outlawed; was placed upon the list of exiles and all his possessions were confiscated.

"Honor took refuge in the camp." In this short sentence historians pretend to give an idea of the terrible years 1793 and 1794 of our revolution. But the great epochs of history can be described in so few words, only at the expense of truth. It is true the armies of the republic manifested a devotion, a patience, and a courage really admirable; it is true the soldiers, badly armed, badly clothed, barefooted, strangers to the most simple military evolutions, hardly knowing how to use their guns, overcame by force of patriotism the best troops of Europe, and drove them disorganized beyond the frontiers; yes, from the bosom of the people, whose intelligence had been dwarfed by the aristocratic pride and prejudices of our ancestors, sprang as if by enchantment immortal leaders; yes, when the welfare or honor of the country required it, the son of an humble goat-herd became the illustrious head of one of our armies, the conqueror of Marshal Wurmser and the peace-maker of the Vendée; yes, the son of a simple tavern-keeper precipitated himself, like an avalanche from the heights of the Albis, and dispersed from under the walls of Zurich the Russian forces of Korsakoff, even at the moment when they considered themselves marching surely to the conquest of France; yes, the son of a plasterer with a few thousand men gave at Heliopolis such proofs of skill and of bravery that the phalanx of Macedonia and the legions of Cæsar can no longer be called the most valiant troops which have trodden the land of Egypt.

I deplore, I denounce, as vehemently as any one, the sanguinary acts which stained the years 1793 and 1794, but I cannot regard our glorious revolution only under this sad aspect. I find, on the contrary, much to admire, even amid the cruel scenes which marked the various stages of its progress. Can we cite, for instance, any country, ancient or modern, in which the victims of both sexes and all parties have given greater proof at the foot of the scaffold of resignation, of force of character, of ready sacrifice of life, than was manifested by our unfortunate compatriots? Nor should be forgotten the intrepid assiduity manifested by many honorable citizens in assisting and sheltering the proscribed.

This last reflection brings us back to Condorcet and the admirable woman who concealed him for more than nine months. It may be supposed that Condorcet did not fully measure all the gravity, all the importance, of the article which he published after the adoption of the constitution of the second year. This mistake, however, must be corrected. That which presented itself to the mind of the deputy of Aisne as a duty, he accomplished with full knowledge of the imminent danger incurred. As indisputable proof of this, I find that the publication of the *Address to the citizens of France upon the new constitution* coincides exactly with the steps taken to secure a place of refuge for the author.

In the political as in the terrestrial atmosphere, there are signs that herald storms, recognized at a glance by the experienced, however indefinite they may appear to others. Condorcet, his brother-in-law Cabanis, their common friend Vic-d'Azir, could not be deceived. After his public manifestation upon the subject of the constitution of the year II (of the Republic), the impeachment of Condorcet was inevitable; the thunder-bolt was launched at his head, and it was necessary for him to seek shelter without delay.

Two pupils of Cabanis and of Vic-d'Azir, who have since become distinguished members of this Academy, MM. Pinel and Boyer, suggested that he should resort for this purpose to No. 21 Servandoni street, where they had resided. This house, ordinarily occupied by students, belonged to the widow of Louis François Vernet, a sculptor and near relative of the great painters of that name. Madam Vernet, as well as her husband, was born in Provence. She had a warm heart, a lively imagination, a character open and frank; her benevolence amounted to self-sacrifice. These qualities obviated the necessity of circumlocution and long negotiation. "Madam," said MM. Boyer and Pinel, "we wish to save a proscript." "Is he an honest man; is he virtuous?" "Yes, madam." "In that case, let him come!" "We will tell you his name." "You can tell me that later; lose not a moment; while we speak together, your friend may be arrested."

That same evening Condorcet intrusted his life to a woman whose existence even a few hours before was unknown to him.

Condorcet was not the first fugitive received at No. 21; one other had preceded him there. Madam Vernet never consented, in regard to this unknown, to satisfy the natural curiosity of the family of our confrère. Even in 1830, after nearly thirty-seven years had elapsed, her answers to the pressing questions of Madam O'Connor never passed beyond vague generalities. The refugee, she said, was a great enemy of the revolution; he lacked firmness, was frightened by the least noise in the street, and did not quit his retreat until after the 9th Thermidor. The excellent woman added, with a smile and some sadness, "Since that time I have not seen him; how do you suppose I can recollect his name."

Our confrère had hardly entered his retreat in Servandoni street, when he became a prey to the most cruel mental torture. His income was seized; he could not dispose of a straw belonging to him. For himself, personally, he did not suffer on this account, for Madam Vernet provided for his necessities; with this incomparable woman to assist an unfortunate was so much a matter of duty, that afterward, when the family of the illustrious secretary became opulent, they endeavored in vain, with repeated and constantly-renewed efforts, to induce her to receive some remuneration.

But, safe himself, "Where," thought the illustrious academician, "will she live who is so unfortunate as to bear my name to-day, when every noble woman, and much more every wife of a proscript, is excluded from the capital?" "Trust to the resources of a devoted wife." Madam Condorcet managed to come into Paris every morning with the purveyors of the markets. "But how will she support herself?" still demanded our confrère in his uneasy solicitude. It seemed, in fact, impossible that a lady delicately reared, accustomed to be served and not to serve others, could gain by her own exertions sufficient maintenance for herself, her young daughter, her sick sister, and an old housekeeper. But the apparently impossible was soon in fact accomplished. The need of some representation of the lineaments of relations and friends is never greater than during a revolution. Madam de Condorcet passed her days in making portraits now in the prisons, and these were the most in demand; now in the silent retreats the charitable secured for the proscribed; in the brilliant drawing-rooms, or in the modest habitations of citizens of all classes who considered themselves threatened by approaching danger. The skill of Madam Condorcet also rendered much less vexatious, much less perilous, the frequent raids of detachments of the revolutionary army upon her dwelling-place of Auteuil. Upon the demand of the soldiers she reproduced their features with the pencil or the brush. She exercised over them the fascination of her talents, and almost converted them into protectors. As soon as painting ceased to be remunerative, Madam Condorcet, exempt from prejudices, did not hesitate to open a store for lingerie. Later she became the skilful translator of the work of Adam Smith upon the moral sentiments, and published, herself, some letters upon sympathy equally worthy of esteem on account of their delicacy of perception and their elegance of style.

The first steps, the first successes, of Madam Condorcet in the career of personal abnegation and courageous devotion we have just described were a balm to the almost fainting heart of the unhappy proscript. He felt himself inspired for persevering and laborious work. The force, the clearness of his mind were not less perfect in the retreat guarded by the heroic humanity of Madame Vernet than they were twenty years before, when he was secretary of the Academy of Sciences.

The first work written by Condorcet in his seclusion has never been printed. I will quote the opening lines:

"As I cannot know whether I shall survive the present crisis," writes the illustrious philosopher, "I consider it a duty to my wife, my child, and my friends, who may suffer from the calumnies attached to my memory, to give a simple exposition of my principles and my conduct during the revolution."

Cabanis and Garat were mistaken when they affirmed in the introduction to the *Sketch of the progress of the human mind* that their friend wrote only a few lines of this exposition. The manuscript consists of forty-one closely-written pages, and embraces nearly the whole of the public career of Condorcet. As secretary of the Academy of Moral and Political Sciences, I should perhaps transcribe the whole of this writing, in which the candor, the good faith, and the sincerity of our confrère are so brilliantly manifested; but the specialties of the Academy of Sciences exclude such details. Nevertheless, as it is the manifest duty not only for all academicians but all citizens to free our national history, our common patrimony, from the miserable stains the action of a limited party have impressed upon her, I will give the opinion of Condorcet in regard to the massacres of September:

"The massacres of the 2d of September," he writes, "a stain upon our revolution, were the work of the folly, the ferocity, of a few men, and not of the people, who endeavored not to see what they were unable to prevent. The factious party, few in number, to whom these deplorable events ought to be attributed, were artful enough to paralyze the public power, to deceive the citizens and the national assembly. They were resisted feebly and without system, because the true condition of affairs was not understood."

Is it not a pleasure, gentlemen, to find the people, the true people of Paris, exonerated from all responsibility in the odious butchery, by a man whose enlightened understanding, patriotism, and high position are a triple guarantee of truthfulness? In future the following apostrophe of a workman to the commune will not stand alone as an isolated expression of individual opinion:

"You pretend to be destroying the enemies of the country. I do not call unarmed men such. Lead to the Champ de Mars these unfortunates who, as you say, would rejoice in the failure of the republic. Let us meet them equal in numbers, equal in arms, and there will then be nothing in their death to cause us to blush."

Condorcet bore his seclusion with great resignation until he heard of the tragical death of the Girondist conventionalists, who had been condemned on the same day as himself. This terrible circumstance concentrated all his thoughts upon the danger incurred by Madame Vernet. He had an interview with his brave protectress, which, although it seems like sacrilege, I give without changing a single word:

"Your kindnesses, madam, are engraved upon my heart with ineffaceable lines. The more I admire your courage, the more I feel it my duty as an honest man not to impose further upon it. The law is positive: if I am discovered in your dwelling, you will have the same sad end as myself. I am an outlaw; I cannot remain longer." "The convention, monsieur, has the right to put you beyond the amenities of the law, but has not the power to place you beyond those of humanity; you will remain."

This admirable answer was immediately followed by the organization in No. 21 Servandoni street of a system of surveillance to prevent the departure of the illustrious refugee, in which most of the members of the household, and particularly the humble porter, had a part. Madam Vernet inspired with her own virtue all those who surrounded her. From this day Condorcet did not make a movement which was not observed.

At this time occurred an incident which shows the superior intelligence of Madam Vernet, and her profound knowledge of the human heart.

One day as he was mounting the staircase leading to the chamber he occupied, Condorcet encountered the citizen Marcos, deputy solicitor to the convention for the department of Mont Blanc. Marcos belonged to the section of the mountaineers; he had been lodging for several days with Madam Vernet. Under his disguise, Condorcet had not been recognized; but was it possible to count upon this good fortune for any length of time? The illustrious proscript confided his uneasiness to his devoted hostess. "Wait," said she, "I will arrange this matter immediately." She ascended to the chamber of Marcos, and, without any preamble, addressed these words to him: "Citizen, Condorcet dwells under the same roof with yourself; if he is arrested it will be you who has denounced him; if he perishes it will be you who has caused his head to fall. You are a benevolent man; I have no need to say more." This noble confidence was not betrayed. Marcos entered, even at the peril of his life, into direct relations with Condorcet. It was he who provided him with the romances which our confrère devoured in large numbers. Madam Vernet felt that through the restlessness of the prisoner, an accident might at any time betray him; that her efforts would in the end prove to be in vain if his mind were not more seriously occupied. At her instigation, Madam de Condorcet, and the friends of her husband, entreated him to devote his time to some important composition. Condorcet yielded to their counsel, and commenced his *Sketch of a historic picture of the progress of the human mind.*

While thus, through the judicious influence of Madam Vernet, Condorcet turned his scrutinizing gaze on the social condition of the past and future human race, he succeeded in diverting his thoughts completely from the terrible convulsions in which France was then struggling. In the *Sketch of the progress of the human mind* there is not a line in which the acrimony of the proscript has taken the place of the cool reason of the philosopher and the noble desire to promote the advance of civilization. "Everything tells us that we are on the eve of one of the great revolutions of the human race. * * * The present indications are that it will be a happy one." Thus Condorcet wrote when he was hopeless of escape from the active pursuit of his implacable persecutors; when the sword of death waited to fall only until the identity of the victim could be assured.

It was in the middle of March, 1794, that Condorcet wrote the last lines of his essay; to carry the work further without the aid of books was not in the power of any human mind. The work did not see the day until 1795, after the death of the author. The public received it with universal approbation. Two translations—one English, one German—made the *Sketch* very popular abroad. The convention obtained three thousand copies, which were distributed through the efforts of the committee of public instruction over the entire republic. In the autograph manuscript the work is called not a *sketch* but a *Programme of a historical picture of the progress of the human mind.* Condorcet indicates its object in the following terms:

"I intend to confine myself to the general traits which characterize the various phases through which the human race must pass, which sometimes manifest its progress, sometimes its decadence, which betray causes and show their effects. * * * It is not the science of man in general that I undertake to treat; I wish to show solely how, through time and his own efforts, he has been able to enrich his mind with new truths, to perfect his intelligence, to extend the use of his faculties, and to employ them to better advantage for his own happiness and the common good."

The work of Condorcet is too well known to require analysis here. How, moreover, can a *programme* be analyzed? I will merely draw the attention of unprejudiced minds to the curious chapter where, dwelling upon the future progress of the human mind, the author shows the necessity, the justice (these are his expressions) of establishing an entire equality of civil and political rights between the individuals of the two sexes, and proclaims, besides, the indefinite perfectibility of the human race.

The latter philosophical idea was opposed with extreme violence in the beginning of this century by all the popular writers. According to them the doctrine of indefinite perfectibility is not only untrue, but productive of disastrous consequences. The *Journal des Débats* presented it "as favoring too much the projects of the seditious." In the severe criticism made of it in the *Mercure*, in reference to a work of Madam de Staël, Fontanes flattering the passions of Napoleon, even maintained this dream of perfectibility to be a terrible menace to governments. Finally, to weaken (according to the ideas of the day) the rights of this philosophical doctrine to any serious consideration, it was pretended that Voltaire was its first, its true originator. This assertion, however, could not well be sustained. The idea of perfectibility is in fact found in Bacon, in Pascal, in Descartes. Nowhere, however, is it more clearly expressed than in this passage from Bossuet: "After six thousand years of observation the human mind is not yet exhausted; it investigates, it discovers still, and may do so to infinity; idleness alone can limit its knowledge and its inventions."

The merit of Condorcet in regard to this particular subject is confined to having studied by means of data furnished through modern science, and by ingenious association of the facts obtained, the hypothesis of an indefinite perfectibility relative to the duration of the life of man, and his intellectual faculties. But he was, I believe, the first to extend the system so as to induce the hope of the indefinite perfection of the moral faculties. Thus I read in his work "that a day will come when our interests and our passions will have no more influence upon the judgments which control the will than they have now upon scientific opinions." Here, without entirely differing from the author, I would say he makes a prediction it will require a long time to fulfil.

The programme was originally intended to have been followed by a *Tableau complet* (a complete picture) of the progress of the human mind. This picture, composed principally of facts, of historical documents, and of dates, was not finished. The editors of 1804 published some fragments of it; other portions are found in the papers of M. and Mme. O'Connor. Let us hope that filial piety will favor the public with the rest. I dare to hope that it will establish the judgment given by Daunon of the sketch: "I do not know any one, however erudite, either of this or any other nation, who deprived as Condorcet was of books, and with no other guide than his memory, could have composed such a work."

As soon as the fever of authorship of our confrère was abated, his fears of the danger incurred by Madam Vernet by his presence in Servandoni street were renewed. He then, to use his own words, resolved to quit a retreat which the unlimited devotion of his tutelary saint had transformed into a paradise.

Condorcet was so well assured of the probable consequence of the step he was about to take, the chances of safety appeared to him so slight, that before leaving the protection of Madam Vernet he recorded his last wishes. This document, which I have in my hands, manifests throughout an elevated mind, a feeling heart, and a beautiful soul. I dare even to say that in no language can there be found anything more thoughtful, more touching, more graceful in form than some passages in this testament, the last effort of our confrère, which he called *The advice of a proscript to his daughter*. I regret that time does not permit me to make some quotations from it. These lines, so clear, so full of delicate and natural feeling, were written by Condorcet on the very day when he was about to expose himself to great danger. The feeling that a violent death was almost inevitable did not disturb him; his hand traced these terrible expressions, *my death, my approaching death*, with a firmness the stoics of antiquity might have envied. Sensibility, on the contrary, overcame his strength of mind when the illustrious proscript considered that Madam de Condorcet might be included in the violent death which threatened him. When obliged to mention this terrible contingency, he no longer speaks directly to the point, but endeavors, if we may so say, to veil from his own eyes the horrors of the situation by ambiguous expressions—"If my daughter is destined to lose both parents." This is the most explicit reference he makes to the subject in all the writing; and then, as if even this was too much for him, he immediately reverts to the support of his child, then only five years old. He hopes that his dear Eliza will remain with his benefactress. He foresees and provides for everything. Eliza will call Madame Vernet her second mother; she will learn, under the direction of this excellent friend, besides the usual occupations of woman, how to design, paint, and engrave sufficiently well to gain a living. In case of necessity, she might apply for assistance in England to Lord Stanhope, and Lord Dean; in America, to Bache, grandson of Franklin, and to Jefferson. She should therefore be taught the English language; this, moreover, was the wish of her mother, which was, in itself, enough. At the proper time, Madam Vernet will cause to be read to Mademoiselle Condorcet the instructions of her parents from the original manuscript (this circumstance is especially indicated). Eliza must be kept free from any desire for revenge, must be taught to overcome what would naturally be, under the circumstances, her filial tendencies in this respect. This was a sacrifice demanded of her in the name of her father. The will terminates with these lines: "I say nothing of my feelings toward the generous friend (Madam Vernet) for whom this document is intended;

let her put herself in my place, then question her own heart, and she will know them all."

Thus Condorcet wrote, on the morning of the 5th of April, 1794. At ten o'clock he left his room in his usual disguise, a vest and large cap, of wool, and descended to a small apartment on the ground floor, hoping to elude the surveillance of which he was the object, and make his escape; but finding Madam Vernet there, he entered into conversation with another inmate of the house* who was present, interlarding his discourse with Latin phrases and making it in every way as tedious and uninteresting as possible, in order to drive her from the room, but in vain. The proscript was in despair, when, by chance or by calculation, he manifested annoyance at having forgotten his snuff-box. Madam Vernet, always kind, hastened to mount the stairs in order to look for it. Condorcet seized this moment to rush into the street. The distressed cries of the portress immediately informed Madame Vernet what had happened, and that she had lost the fruit of nine months' unexampled devotion; the poor woman fell back fainting. To avoid a pursuit, which would have ruined his benefactress, Condorcet passed rapidly through Servandoni street. Stopping to take breath, as he turned into the street Vaugirard, he saw at his side M. Sarret, the cousin of Madame Vernet. The proscript had hardly time to utter some words of farewell, in which admiration was mingled with affectionate gratitude, when M. Sarret said to him, with a firmness that admitted of no resistance, "The costume you wear does not disguise you sufficiently; you do not know your road; alone you will never succeed in escaping the active surveillance of the argus-eyed sentinels the commune has placed at all the gates of Paris. I have therefore determined not to leave you."

It was at ten o'clock in the morning, in broad sunlight, in a frequented street, at the door even of the terrible prisons of Luxembourg and of Carmes, out of which none ever came, except to go to the scaffold; it was in full view of lugubrious notices, declaring in large characters that the punishment of death would be inflicted upon any one who rendered assistance to the proscripts that M. Sarret attached himself to our proscript. Was not this intrepidity equal at least to that of a body of soldiers who throw themselves upon the thundering artillery of a redoubt? The two fugitives escaped by a sort of miracle the dangers which attended them at the barrier of Maine, and then directed their steps toward Fontenay-aux-Roses. The journey was long, after nine months of absolute inactivity had unfitted our confrère for walking. At last, about three o'clock in the afternoon, Condorcet and his companion arrived without mishap, but extremely fatigued, at the door of a country house, occupied by a happy family, who for nearly twenty years had received from Condorcet distinguished services and marks of favor without number. There ended

* This man was named Sarret; was an author of several works. He had married Madame Vernet, but the marriage was kept secret, as the lady did not wish to give up her maiden name.

the dangerous mission Sarret had undertaken; he left Condorcet and returned to Paris.

What happened then, accounts do not agree. As far as I can learn, Condorcet solicited hospitality only for a single night. Certain difficulties, of which I will not make myself the judge, prevented his friends from granting his request; nevertheless they arranged that a small garden door opening outward toward the country should not be closed at night, and that Condorcet might present himself there at ten o'clock. When taking leave of the unfortunate proscript, they presented him with the Epistles of Horace, a poor resource in truth for one obliged to seek a refuge in the dreary darkness of the quarries of Clamast. These old friends of Condorcet undoubtedly committed the irreparable fault of delegating to others, and not seeing themselves that the arrangement made was carried out. For one or two days afterward Madam Vernet who passed over the country of Fontenay-aux-Roses in every direction, in the hope that her presence there might be useful to the fugitive, remarked a mound of earth and tuft of grass in front of the little gate, proving, alas, only too well, that for a long time it had not turned on its hinges; during two dreary nights no door had been open for him, except in Servandoni street. There at No. 21 during a whole week front door, shop door, or alley-door would have yielded to the slightest pressure of the fugitive's finger. In the possibility, I can hardly say the hope of a nocturnal return, Madam Vernet did not think of the thieves and assassins who at that time especially haunted Paris. Great, alas, was the difference in conduct of the two families, with whom ties formed in prosperity by favors conferred and ties of misfortune had connected Condorcet.

On the 5th of April, at two o'clock, we see Condorcet leaving with resignation, but not without sadness, the country house where he had hoped to pass twenty-four hours in security. No one will ever know the anguish, the sufferings he endured throughout the 6th. On the 7th we see him, wounded in limb and impelled by hunger, enter an eating-house of Clamart, and ask for an omelette. Unfortunately this man, of almost universal information, did not know even approximately how many eggs a workman eats at a repast. When asked by the shopman how many he desired, he answered a dozen. This unusual number excited surprise, soon suspicion, which spread quickly. The stranger was requested to exhibit his passport; he had none. Pressed by questions, he called himself a carpenter, but the state of his hands contradicted the assertion. The municipal authorities were informed, had him arrested, and sent him to Bourg-la-Reine. On the route a kind vine-dresser meeting the prisoner, seeing his wounded limb and his limping walk, generously lent him his horse. I ought not to pass over this last mark of sympathy received by our unfortunate confrère.

On the 8th of April (1794), in the morning, when the jailer of Bourg la Reine opened the door of the dungeon in which the unknown prisoner had been confined, in order that the *gendarmes* might conduct him to Paris, he found only a corpse. Our confrère had escaped the scaffold by a dose of concentrated poison he had for sometime carried in a ring.*

Bochard de Saron, Lavoisier, La Rochefoucauld, Malesherbes, Bailly. Condorcet—such were the losses sustained by the Academy during our sanguinary struggles. The memories of these illustrious men have fared very differently; some have rested in peace in the universal and well-deserved regret; others have periodically been subjected to the storm of political abuse.

If my powers obey my will, I hope soon in this place to speak to you of Bailly. To-day I shall not feel that I have accomplished my sacred task, even after all that has been said, if I do not free the memory of Condorcet from a calumnious imputation. The form of this accusation against our brother does not lessen my inquietude; it imputes to him only weakness, but weakness under some circumstances is a crime.

In giving an account of the deplorable condemnation of Lavoisier, a pen very wise, very respectable, and very respected, wrote some years ago: "Much hope was felt for Lavoisier on account of certain circumstances some of his confrères could adduce in his favor; but terror froze their hearts." With this as foundation, a certain public, cruelly trifling, numbered upon their fingers the academicians who had seats in the convention, and so, without further examination, the name of our former secretary is found fatally implicated in the stupidly ferocious act which deprived France of an excellent citizen, the world of a man of genius. Two dates, two simple dates, will show that when no names are mentioned in connection with so grave an event, when only general terms are used and no one is especially accused, it is not wise, to say the least, to implicate everybody.

Condorcet, it has been said, might have interfered in favor of Lavoisier. When?—at the time of the arrest? Then this is my answer: Lavoisier was arrested in the month of April, 1794. Condorcet was proscribed and hidden with Madam Vernet from the commencement of July, 1793. After the sentence of the revolutionary tribunal? The response is still more decisive: Lavoisier died on the 8th of May, 1794. Condorcet poisoned himself at Bourg là Reine a month before, on the 8th of April. I need not add a word to these figures; they will remain imprinted by ineffaceable lines upon the foreheads of the calumniators of our noble confrère.

PORTRAIT OF CONDORCET.

I have successively presented to your eyes, and in what has appeared to me the true light, the savant, the literateur, the political economist, and the member of two of our national assemblies. It remains for me to

* This poison (we do not know its nature), was prepared by Cabanis. That with which Napoleon attempted to poison himself at Fontainebleau was of the same origin and the same date.

give the portrait of the man of society, to speak of his exterior appearance and of his manners. At one time I was in despair of fulfilling this part of my task, for I had not known personally the secretary of the Academy. I had never even seen him. I knew too well, besides, that books are very unfaithful guides to a knowledge of their writers; that authors can assume sometimes in their works a character totally at variance with their habitual actions. The maxim of Buffon had often been contradicted by fact: "A man's style is the man himself." Happily, unpublished correspondence has in a manner transferred me into the family of Condorcet; has shown him to me surrounded by his relations, his friends, his confrères, his subordinates, and his clients; has made me the witness, the confidant, I had almost said, of all his actions. So I feel reassured. Need I fear to speak with boldness of the most secret thoughts of the illustrious academician, of his private life, of his most sacred feelings, when I have for guides and references Turgot, Voltaire, d'Alembert, Lagrange, and a woman (Mademoiselle de L'Espinasse) celebrated by the extent, the penetration, and the delicacy of her mind?

Condorcet was of large stature; the immense size of his head, his large shoulders, his robust body, contrasted with limbs which had always remained slight on account, our brother thought, of the inactivity which his costume of a girl, and the too great solicitude of his mother, imposed upon him during the first eight years of his life.

Condorcet always retained, with great simplicity, something approaching to awkwardness. To see him only in passing, it would have been said, That is a good man, rather than, That is a wise man. His principal trait, his truly characteristic quality, was an extreme kindness, which was in accordance with the gentle expression of a beautiful face.

Condorcet was considered by his mere acquaintances as cold and insensible. This was a great mistake. He never, perhaps, addressed affectionate expressions to his relatives and friends; but he never lost an opportunity of giving active proof of his attachment. He was afflicted with their afflictions; he suffered from their misfortunes to such a degree that his sleep was often disturbed and his health affected.

How does it happen, then, that our confrère has been so frequently accused of insensibility? Because the emotions of his noble soul were not manifested readily in his countenance. He would listen with an air of the utmost indifference to the story of an unfortunate; but while others were content to manifest their sympathy in vain words, he, without saying anything, would bring succor and consolation of all kinds to relieve the sufferings which had been revealed to him. You know now the true meaning of the words of d'Alembert, "Condorcet is a volcano covered with snow." It is a great mistake to suppose the immortal geometer, by his picturesque simile, meant to indicate violence of character, disguised by coldness.

D'Alembert had seen the volcano in full action in the year 1771. The geometer, the metaphysician, the political economist, the philosopher, Condorcet, entirely overwhelmed by an affair of the heart, had then become for all his acquaintances an object of pity. He even thought of committing suicide. The manner in which he rejected the palliative for his grief, recommended by his friend and confidant, Turgot, is interesting: "Make some verses; it is a kind of composition you are unaccustomed to, and will distract your mind." "I do not like bad verses; I could not endure my own." "Attack some deep problem of geometry." "When a depraved taste has supplied us with aliment of strong flavor, all other food is displeasing to us. The passions are a degradation of the intellect; outside of the feeling which absorbs me, nothing in the world interests me." As a physician tries all remedies in desperate cases, Turgot then endeavored to excite the fortitude of his friend by examples taken from ancient and modern history and even mythology, but all in vain; time alone could cure, time alone did cure, in fact, the wound which rendered our confrère so unhappy.

If the public were wrong in accusing Condorcet of insensibility, they were equally mistaken in considering him indifferent in matters of art.

When at the French Academy was read for the first time one of those literary productions which formed the glory and the honor of the eighteenth century, Condorcet would remain completely impassive in the midst of the most enthusiastic manifestations of admiration for the author, would hardly seem to have listened, but as soon as opportunity offered he would analyze minutely the work, appreciating its beauties and indicating the weak portions with tact and delicacy as well as admirable judgment, while in support of his remarks he would recite without hesitation long quotations in prose or verse which had become engraved upon his most remarkable memory.

The reserve Condorcet imposed upon himself before strangers gave place in social intercourse to a gayety, simple, refined, and slightly epigrammatic in expression. It was then the immense variety of his knowledge was revealed. He spoke with equal clearness, equal assurance of the rules of geometry, and the regulations of the palace; of philosophy and the genealogy of the court people; of the customs of the republics of antiquity, and the trifles of society.

The secretary of the ancient Academy of Sciences descended into the polemic arena only to defend his friends against the attacks of mediocrity, of hate, and of envy. But his courageous devotion did not lead him to share the unjust prejudices even of those to whom he was most tenderly attached. This kind of independence is so rare I must give some examples of it.

D'Alembert, unconsciously influenced by a feeling of jealousy, did not render full justice to Clairaut. Yet we find Condorcet, in his eulogies of M. de Trudaine and of M. d'Arci, referring almost unnecessarily to the relations of these savans with the author of the beautiful work upon the figure of the earth, while he does not hesitate to call Clairaut a man of genius and to speak of the wonders he accomplished in his youth.

Lagrange and d'Alembert had a very low opinion of the *Lettres d'Euler à une Princesse d'Allemagne.* They had even gone so far as to call them, in allusion to a feeble work written by Newton in his old age, "the commentary upon the apocalypse of Euler"; Condorcet regarding them from another point of view found the letters useful, and not content with praising them, became the editor of them, without the slightest suspicion that this independence of opinion might cause umbrage to his best friends.

The book of Helvétius had irritated Turgot, who expressed himself very emphatically about it, in his correspondence. Upon this point the celebrated intendant of Limoges was impatient of contradiction. Condorcet nevertheless maintained his own opinion of the work with great firmness; he was far from considering it irreproachable, but thought that its dangerous tendencies were exaggerated.

Vanity reigns supreme in all classes of society, particularly, it is said, among men of letters. We can nevertheless affirm that this active and universal stimulant of our actions never affected the beautiful soul of our former confrère. A number of circumstances give evidence of this rare phenomenon. Jealousy is the just punishment of vanity; yet Condorcet never experienced this cruel infirmity. When absorbed by his arduous duties as secretary of the Academy, and by his literary and political engagements, our confrère was obliged to renounce the great and pure pleasure of scientific discoveries; he nevertheless wrote to Euler, to Lagrange, to Lambert (d'Alembert was sick at that time), "Give me news of your work; I am like one of those old gourmands, who, unable longer to digest, still take pleasure in seeing others eat."

Condorcet carried so far his desire to be useful that his door was never closed against any one; he was always accessible; he received every day without impatience, without even appearing to be fatigued, the interminable visits of the legions of troublesome and idle fellows who abound in all great cities, especially Paris. Considering the value of his time, this was kindness carried to heroism. As to Condorcet's disinterestedness, I need not speak of it, as it is well known. "In ethics," he wrote in a letter to Turgot, "I am an enemy to indifference and a friend of indulgence." The phrase would not represent the truth if taken in an absolute sense. Condorcet was very indulgent toward others but very severe with himself. He was very independent in action, so much so as to injure himself seriously by considering certain forms of politeness, current in society, as species of small change too trifling to be taken into account. As an example of his disregard of popular opinion, especially where a principle was concerned, I give the following incident: M. de Maurepas was very much irritated by a letter directed against Necker, and in which occurred some passages which could be injurious to the public credit. It was wrongfully attributed to Condorcet. The Duke de Nivernais endeavored to persuade his friend and confrere to write to the minister, but he resisted with a firmness which, at the time, seemed inexplicable. To-day I find the explanation in an unpublished letter addressed to Turgot. The secretary of the Academy would not pay even the semblance of respect to a man whom he was far from respecting.

Condorcet acknowledged his faults and the errors he committed with a frankness of which the following brief incident is an example: "Do you know," said some one to him, "the circumstances which caused the rupture between Jean Jacques and Diderot?" "No," he answered, "I only know that Diderot is an excellent man, and whoever involved him in dissension was wrong!" "But it was yourself?" "Then I was wrong!"

In the edition of Pascal's thoughts, by the author of Mérope, I find this note of Condorcet: "The expression, 'honest men,' signified originally men of probity; in the time of Pascal, it indicated men of good society; now it is applied to men of title or of money." "No," said Voltaire, addressing himself to the annotator, "the honest men are those at whose head you stand."

To justify this exclamation, since it seemed to me the expression of truth, has been my object in writing these pages. I shall be happy if the portrait I have traced of the illustrious perpetual secretary of the ancient Academy of Sciences has dissipated the very cruel prejudices, neutralized the effects of the more detestable calumnies which have injured his memory; if, with those who enjoyed the intimacy of Condorcet, I have made you see in him a man who has honored science by his labors, France by his high qualities, humanity by his virtues.

LOUIS AGASSIZ:

A BIOGRAPHICAL NOTICE.

By Ernest Favre.

[Translated for the Smithsonian Institution* by M. A. Henry.]

The name of Agassiz, for twenty years intimately connected with the history of science in America, has nevertheless retained its popularity in Switzerland, where his works have a great celebrity. It is in our country that he was born, in our country he acquired renown, and Switzerland can never forget that he is among the number of her children. Without other resource than his intelligence and his energy, he rose to the first rank among the eminent men of science of our country. We desire in these few pages, as a souvenir of this great scientist, to notice briefly the various phases of his life and the principal subjects of investigation he pursued.†

I.

Louis Jean Rodolphe Agassiz was born on the 28th of May, 1807, in the rectory of the village of Motier, situated in the canton of Friburg, on the shore of Lake Morat. Nothing in his family nor in his surroundings gave promise of the brilliant destiny which awaited him. His ancestors had filled the office of pastor for six generations; his father, deprived of fortune, had embraced the hereditary occupation. It was then entirely to his own energy, his talents, and his genius that he owed the high position he afterward attained.

There is little to be said of his early years. From his infancy the observation of animals was one of his greatest pleasures. He passed many hours fishing in the lake and in studying the habits of fishes; he watched with interest the metamorphoses of the caterpillar. The same taste was manifested both at Bienne, where he pursued his studies in the college, and at Orbe, where he resided later, by his passion for collecting insects and plants, and he was often heard explaining with enthusiasm to his younger brother phenomena of nature he as yet but imperfectly under-

*From the "Archives des Sciences de la Bibliothèque Universelle, Genève, Mai 1877, tome LXIX."

†In the "Catalogue of Scientific Papers," published by the Royal Society of London, is found a list of 130 publications made by Agassiz. This list includes only articles which have appeared in scientific periodicals. To it must therefore be added all his various works published separately, as well as his numerous contributions since the year 1863, at which date the above catalogue terminated.

stood. The course of the Academy of Lausanne afterward turned his attention toward classical studies.

When he arrived at the age to choose a profession his parents desired to procure for him a commercial apprenticeship, but he obtained instead permission from them to pursue the study of medicine, which could give him both the means of providing for his support and the opportunity of continuing the study of natural history, for which he felt a decided vocation. He passed two years at Zurich, then a winter at Heidelberg, where Bischoff, Leuckardt, and Tiedemann were professors. While at this university fishes were still one of his favorite studies. He already began to classify them and to make drawings of them, and thus accumulated material which later was of great service to him.

In the autumn of 1826 he went to Munich, where the chairs of natural history were occupied by men of the first rank. Oken Martius received him with kindness; Dœllinger, the illustrious professor of embryology, took him under his protection, made him a member of his household, and developed in him a taste for this science, to which Agassiz always attached great importance. At this time the young student had already excited great anticipations for his future; soon his masters and comrades, among whom we find the botanists Schimper, and Braun, and Burckhardt, his draftsman, were his friends, and he became the center of an eager group of scientists. "When we assembled," he wrote, "for conversation, or to give each other lectures, as was frequently our custom, our professors were often among our auditors, and encouraged us in our efforts for individual research. My room was the place of meeting—bedroom, work-room, museum, library, lecture-room, and fencing school, all in one. Students and professors called it the Little Academy."

The four years he passed thus at Munich in the study of medicine, of the natural sciences, and even of philosophy, with all the hope, the enthusiasm of youth, were among the happiest of his life, and he always cherished a pleasant recollection of them; moreover, it was during this period that his future career was definitely decided. Martius and Spix had only a short time before returned from an expedition to the river Amazon, and Spix had since died, having only commenced the description of the fishes collected. Martius requested Agassiz, somewhat prepared for the subject by his own studies, to take charge of the work. The young student acquitted himself of his difficult task with honor, and this was the commencement of his reputation. The work appeared in 1829.* The same year Agassiz received the doctorate of philosophy. The following year he was admitted to practice as doctor of medicine, and went to Vienna in order to study, in the collections of that city, the fishes of the Danube.

He was recalled to Switzerland by his father, who demanded that he should return there and practice medicine; but he succeeded in obtain-

*Selecta genera et species piscium quos collegit et pingendos curavit, Dr. I.-B. de Spix; digessit, descripsit et observationibus illustravit, Dr. L. Agassiz.

ing a delay, and after a brief sojourn in Vienna went to Paris, where he conceived a strong desire to bring himself into relation with the pleiades of celebrities of the Museum of Natural History. Cuvier, Blainville, Valenciennes received very kindly the young doctor. He saw frequently Humboldt, who was then in the height of his renown, and who gave him substantial proof of his friendship by furnishing him the means of prolonging his stay in Paris. *

The interest felt by Agassiz in the investigation of fishes increased with his knowledge of the subject. He found in Paris one of the most complete collections, and a beautiful series of fossil fishes from Monte Bolca belonging to Count Gazzola. He undertook the description of the latter. This was his first step in paleontological research. Cuvier, who soon observed in the young naturalist signs of rare ability, placed generously at his disposal material collected for a history of fossil fishes, and this influential encouragement decided his career.

Zoölogy alone did not satisfy his powers of generalization, and he soon recognized that paleontology was its indispensable complement. The division of the animal kingdom into branches, classes, orders, families, genera, and species, was not in his opinion merely a system, invented to simplify research, but a divine institution; according to his view, this great plan of creation existed from the beginning, and the organisms now found upon the surface of the globe form a part of it as well as those whose remains are found in the most ancient deposits. The nature of fossils, the entire system of their organization, prove in the most conclusive manner the existence of this primitive plan, which has developed regularly up to the present period. Paleontology furnishes thousands of species, of genera, and even of numerous families, which to-day have entirely disappeared, and which constitute an important part of this great plan. To base a zoölogical classification upon living organisms is to make a whole of a small part, is to eliminate arbitrarily from the divine system the majority of the elements of which it is composed. The great work of Cuvier had suddenly revealed the importance of paleontology. In his investigation of fossil bones he laid the foundation of this science, by showing that the species found below the surface of the globe are different from those living at the present time. He had established the laws of the *unity of plan* which allowed the conception of ancient from existing forms; and the law of *concordance of characters*, which, establishing the necessity that all parts of an organism are disposed for the same end, authorized the deduction from each of them of the character of the other parts, as well as of the kind of life of the animal. †

To understand an extinct type we do not need to have it entire under our eyes. The solid parts (which are alone preserved) not only give us sufficient characteristics to class it in the genus and the species to which

*Letters of Agassiz to Louis Coulon, Mem. Soc. Phys., Genève, 1874, XXIII, 472.

† Pictet, Traité de Paléontologie. Introduction.

it belongs, but a mere fragment of this frame-work, a single bone, a jaw, a tooth is in most cases enough for this purpose.

These principles are based, above all, upon the comparative anatomy of living animals, the study of which is indispensable to a knowledge of extinct types. Agassiz applied them to that of fossil fishes, the collections of which contained at that time many specimens which had not yet been examined. The public and private museums of England furnished most of the material for his investigations, but those of the continent were also made to contribute.

II.

Hitherto we have seen Agassiz utilizing for the profit of science the great resources placed at his disposal. His return to Switzerland, in 1832, makes us acquainted with a new attribute of his great mind, the talent for creation and organization. The liberal encouragement of Louis Coulon, and among others that of Humboldt, who exercised a great influence over the King of Prussia, then suzerain of Neuchâtel, facilitated the establishment of Agassiz in that city. An annual compensation of 80 louis as professor at the gymnasium, and the sale of his collections for 500 louis, provided the first resources necessary for the continuation of his publications. He had not here, as at Munich and Paris, immense stores of material at his command and illustrious men of science to come to his aid. Everything was in an unformed condition; but he was the pioneer, the chief, and he soon rallied about him a group of naturalists, who recalled upon another theater the "Little Academy" of Munich. The well-known names, Desor, C. Vogt, Gressly, Guyot, Nicolet, of Montmollin, are connected with this period of his life; the first two were his most active collaborators. Several of his fellow-students of Munich—Weber, Dinkel, and Burckhardt—followed him to this new residence, where they labored in the execution of his designs; one of them, a citizen of Neuchâtel, H. Nicolet, opened at his instigation a vast lithographic establishment, where all the plates of his memoirs were executed. The modest chair he occupied became soon the most distinguished of the gymnasium; the collections increased rapidly; the public became interested; a few young men entered into these researches; and thus was founded, in 1833, under the presidency of L. Coulon, the Society of Natural History, of which Agassiz was the secretary and the *soul* for many years. Neuchâtel became an important scientific centre; thence proceeded successively and at short intervals voluminous scientific publications of the first order.

In 1839 he published the commencement of his *Histoire naturelle des Poissons d'eau douce de l'Europe centrale*, which contains the embryology of the Salmonides by C. Vogt. This work, undertaken on a very extensive plan, was never completed.

The history of fossil fishes, begun at Paris, was terminated at this period. The first part appeared in 1833, at his own expense, but his modest resources were not sufficient to continue the work, as it was accompanied by expensive plates.* The Geological Society of London, aided by Lord Enniskillen and Sir Francis Egerton, furnished the means he lacked. A draftsman, Denkel, worked for him constantly for several years. This publication, which may be regarded as a continuation of Cuvier's Researches upon fossil bones, was not finished until 1843. It is the most original work of Agassiz, and one of the principal monuments of his greatness.

There is no class of animals that can furnish elements more important for the history of the development of the organic kingdom, the law of the succession of beings, and the relations of the fossil fauna than the fishes. They alone of the vertebrates appeared in the first ages of the world, and passed through all the phases of creation up to the present time.

An osteology of fishes, a rational classification, the description of a multitude of new species, and theoretic consequences of great importance were the results of the wise researches of Agassiz.

One of the distinctive characteristics of this class of animals is a skin covered with scales of peculiar form and structure; now the nature of this envelope is in direct accordance with the interior organization. The scales, therefore, from this point of view, are of great importance, and may serve as a basis of classification. The author subdivides them into four orders, as follows:

Cycloids.—Scales imbricated, corneous, and without enamel, the posterior edge simple. Skeleton bony.

Ctenoids.—Scales imbricated, corneous, without enamel, the posterior edge indented. Skeleton bony.

Ganoids.—Scales angular, and covered with a layer of enamel, their edges uniting regularly. Skeleton less bony than the preceding, sometimes cartilaginous.

Placoids.—Osseous plates, disposed irregularly, terminated on the upper side by points or hooks. Skeleton cartilaginous.

The last two orders have existed from the first appearance of life upon the surface of the globe. The others commenced with the Cretaceous period, and include most of the fishes of the present time. This classification has since undergone important modifications; it however assisted very considerably progress in the knowledge of this class. The hand of genius, said Pictet, is everywhere manifest throughout this beautiful work.

The monograph of the fishes of the old red sandstone, undertaken at the request of the British Association for the Advancement of Science, and completed in 1844, supplemented the preceding work.† The author

* *Recherches sur les Poissons fossiles;* 5 volumes quarto, with an atlas of 384 plates, in folio, most of the figures being colored.

† *Supplément aux recherches sur les Poissons fossiles. Monographie des poissons fossiles du vieux grès rouge ou système dévonien des îles Britanniques et de Russie.* 4to. 41 pl. 1844–1845.

was obliged to describe a very numerous and entirely new fauna. When he commenced his investigation of fishes, he was not acquainted with any species older than those of the coal strata; the number of these fossils has immeasurably increased since then, and is now counted by thousands. Agassiz recognized that among the living species a small number only have a heterocercal tail; that is to say, one in which the upper lobe is formed by the prolongation of the vertebral column. These animals are the last representatives of a type largely diffused in the Devonian and Carboniferous seas. All the other fishes, on the contrary, have a homocercal or symmetrical tail, at the base of which the vertebral column stops, and does not penetrate either of the lobes. He observed that in the embryo of certain fishes the tail is at first heterocercal, as that of the paleozic fishes, and afterward becomes homocercal. This important discovery, in connection with others of a like nature, permitted him to establish the law that the "embryo of the fish during its development, the present class of fishes with its numerous families, and the type of fish in its geological history, undergo strictly analogous phases," and in a more general way he applies this law to vertebrates; "The successive creations have undergone phases of development analogous to those the embryo passes through during its growth, and similar to the gradations the present creation shows us in its ascending series, considered as a whole." Then rising from the consideration of the fishes to more general views of the phases of creation, he writes: "The most incontestable result of modern paleontological research, in the examination of the question which at present occupies us, is the fact, now beyond controversy, of the simultaneous appearance of particular types of all classes of invertebrate animals from the earliest development of life upon the surface of the globe." The history of this successive development "shows conclusively the impossibility of referring the first inhabitants of the earth to a small number of branches, differentiated from one parent stock by the influence of the modifications of exterior conditions of existence."*

It was in 1844 that Agassiz wrote these lines, and he all his life remained faithful to this opinion. The future will decide whether he was right or wrong; it is true that for the moment the balance does not seem to lie in his favor. It is difficult, indeed, to comprehend why the results of these admirable researches, and of those he made later, did not lead him to sustain the theory of transformation of which they seem to be the natural consequence. Still it is impossible to consider his opposition to this theory as resulting from prejudice, or as resting upon other grounds than pure scientific reason.

Agassiz had a mind too comprehensive, he was too enterprising, to confine his attention to a single class of the animal kingdom, and we find him soon producing a series of works upon a variety of subjects. Thus he undertook, with M. Desor, the study of the Echinoderms; and their

*Introduction to a monograph of the fossil fishes of the old red sandstone, pp. 4, 13.

researches formed the basis of the ulterior investigations of this class. Mr. Desor soon made a specialty of the subject, and to him we owe the publication of several works in the preparation of which Agassiz was only his collaborator. Agassiz also pursued some investigations, as new as they were original, on living and fossil mollusca.*

A large number of articles upon special points of natural history and memoirs containing more general conclusions, succeeded each other rapidly during these years. While these original memoirs exhibited the scientific genius of their author, his numerous lectures, the fruits of his vast erudition, formed the substance of various other works.

One of the principal of these is a catalogue of the genera of all known animals, a work to which several of the most distinguished geologists of that period contributed. At the same time he collected the elements of a zoölogical and geological dictionary published later in London.†

"We have a good working force," he writes to a friend in Geneva; "Gressly is here. Desor is studying the Galerites. I am busy, alternately, with Myas and the fresh-water fishes. Vogt with anatomy. Thus the time passes agreeably and usefully."

The energy he displayed during these years was something astonishing; the history of science presents no other example like it. One of his collaborators gives us a vivid picture of the activity which reigned in the laboratories of Neuchâtel. "It might be supposed," said Mr. Vogt, "that in such complicated machinery the wheels would sometimes have interfered with each other. The printing-office constantly demanded copy, the lithographic establishment designs, and yet the work of his original researches never ceased; hardly had we the time necessary to complete one set of labors before Agassiz had new plans and assumed new tasks. Every thought that passed through his head was converted into a great work, with hundreds of folio plates, hundreds of pages of text; in all this he was the acknowledged master, as well as in the collection of new material for his work. He knew how to draw all Europe into contribution. Often boxes which had been sent for and awaited with feverish impatience remained weeks and even months unopened, because in the meanwhile another subject occupied attention, and the objects they contained had lost their interest."

Order did not prevail either in the abode or in the laboratory of Agassiz. "In my house everything is astray but nothing is lost," he would say to those who came to consult specimens or books he could not find.

The reputation of the young savant extended rapidly. In 1839, at the

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**Mémoire sur les moules des Mollusques vivants et fossiles.* Mém. Soc. Neuchâtel; II.—*Études critiques sur les Mollusques fossiles. Mémoire sur les Trigonies;* 1840.—*Monographie des Myes;* 1842–1845.—*Iconographie des Coquilles tertiaires réputées identiques avec les vivantes;* 1845.

†*Bibliographia Zöologiae et Geologiae.* A general catalogue of all books, tracts, and memoirs on zoölogy, by Prof. L. Agassiz, corrected, enlarged, and edited by Strickland. London, 1848.

age of 32, the Academy of Sciences made him a corresponding member. Large in stature, well formed, endowed with excellent health, with an amiable face, and an eye which beamed with unusual intelligence, Agassiz gained the sympathy of all who approached him. His countenance was frank and open, his manner winning; he animated the reunions of the naturalist and the work of the laboratories by his vivacity and good humor.

"He was," said one of his scientific adversaries (formerly among his devoted friends), "a man full of kindness, of enthusiasm for science, and easily moved by all that is beautiful and good." A warmth which nothing could repress was with him united with facility and charm of expression. Always ready to frame theories, to discuss them, and to advance new ideas, he captivated his auditors by the vigor and clearness of his exposition. His public and class lectures, too, were always extraordinarily successful. Even when he discussed the most abstruse subject his auditors hung upon his lips. The talent for speaking, which he possessed to a high degree, was one of his most valuable means of influence, and contributed greatly to his celebrity.

He was preminently a zoölogist; he distinguished himself particularly by the justness and promptitude of his perceptions. He knew by the first inspection all a collection contained, the new specimens, the types already described, and he remembered admirably what he had seen. He has been accused of being too ready to form new species. The learned geologist of Berlin, Léopold von Buch, whose peculiar face and eccentric costume often excited curiosity, said one day, "When I am at Neuchâtel, and I knock at the door of Agassiz, I am always afraid." "Why?" asked some one. "I dread lest he will take me for a new species." Science has, however, ratified most of the distinctions he established. His just regard for the value of characteristics led him to circumscribe species within narrower limits, and in this respect he had a happy influence upon paleontology.

His zoölogical works, which were numerous enough to have absorbed several ordinary lives, still did not occupy all his time, and a new field of research was opened to him. Let us then, for a moment, leave the museums and laboratories, and transport ourselves to the foot of the glaciers of the Alps, where we will soon see him arrive with his companions.

For some time the attention of naturalists had been drawn to the presence throughout a large part of Switzerland of blocks of various dimensions, composed of rock different in nature from the soil upon which they rest. How did these rocks, to which has been given the name of erratic blocks, and which are of Alpine origin, come to be dispersed over the Swiss plain and upon the Jura? Two theories are given; Leopold von Buch, Élie von Beaumont, and others, maintain that they were transported by water. But their size, sometimes enormous, and the height at which they are found upon the sides of the Jura, render this hypothesis inadmissible. To a Valoisian mountaineer, Perraudin, belongs the honor of solving the problem. Observing that the glaciers, at the present time, carry blocks, which they throw off at their extremity, he explained the dissemination of the bowlders in question by the hypothesis that the glaciers must have extended in times past much beyond their present limits, and brought with them, on their surface, material which they left when they retreated. He communicated this idea to Charpentier, who discussed it with him, and ended by adopting it. The dispersion of the blocks is connected with other phenomena which confirm this origin; the polished and rounded surfaces, the accumulation of angular blocks, the hillocks, which have exactly the form of moraines, the unstratified deposits, in which are found pebbles covered with scratches—all these facts, which are repeated to-day in the immediate vicinity of the glaciers which produce them, also show that these same glaciers once covered the larger part of Switzerland, leaving the traces we have indicated. If Perraudin was the inventor of the theory (1815), if Venetz contributed to its development (1833), it was Charpentier who examined it, studied it, perfected it, made it known (1835), and later disseminated it in the world of science with the authority his standing gave him (1841). "To this ingenious and persevering naturalist," said Alphonse Favre, "should be given the greater part of the glory attached to the discovery of this great scientific truth."

Agassiz having heard of this discovery made a visit to Charpentier for the purpose of combating it. He remained several months with him and left well convinced of the truth of the theory, and full of eagerness to verify the proofs already advanced in its favor, to find new ones, and, in short, to study the subject with the activity he carried into everything. The question had been under discussion for some time when the Helvetic Society of Natural Science met at Neuchâtel, under his presidency, on the 24th of July, 1837. The opening discourse turned upon this question, and fell like a bomb in the midst of the most positive adversaries of the glacial theory who happened to be present at the meeting.

Leopold von Buch, who was not famous for sweetness of temper, was very angry, and would examine nothing, hear nothing in regard to the matter. Agassiz, who had foreseen his opposition, had prepared the following paragraph for the close of his speech to mollify him: "When Mr. de Buch affirmed for the first time, in the face of the formidable school of Werner, that granite is of plutonic origin, and that the mountains were raised, what said the Neptunists? He was at first alone in his support of the theory, and it was only by defending it with the conviction of genius that he made it prevail. Happily, in scientific matters, numerical majorities have never at first decided any question."

Notwithstanding the opposition of these great men, who had themselves contributed so much to the progress of science, the theory gained ground, and is to-day generally admitted.

The basis of these researches was necessarily the study of existing glaciers. Their constitution, their increase, their motion, the influence of temperature, the transportation of blocks, the formation of moraines, were all so many questions to be elucidated. Agassiz threw himself with ardor into this new pursuit, and established himself with Desor, Vogt, and others, upon the glacier of the Aar. They constructed a lodging-place under the shelter of a large block of ice upon the centre morain, and went to work. The following year, the block having melted, they formed a cabin of wood and tent-cloth. It was divided into three chambers; the first was both laboratory and parlor, where they received the savans who flocked from all parts of the country to the *Hôtel des Neuchâtelois*, a name the modest abode has retained in the history of science; the second and third, furnished only with straw, served as bedchambers, one for the naturalists, the other for the guides. It may be imagined that the establishment was not comfortable, and it required an unusual amount of energy to lead such a life during several weeks every year. A letter of Mr. Desor gives some idea of the difficulties encountered: "You are much mistaken," he writes to one of his friends, "if you suppose that all is pleasure, satisfaction, and intellectual enjoyment at the *Hôtel Neuchâtelois*. We have been shut up for three days in our tent unable to venture out, the *gux** is so furious. Do you know what a *gux* is? I think not, and you are happy in your ignorance. I can only say in regard to it that if the founders of the various religions had known of the *gux* they would not have imagined a hell for lost souls, but would simply have sent them to the *Finsteraarhorn*, and secured for them a perpetual *gux*. . . . . It takes hold of the limbs, dries the skin, renders the imagination heavy and obtuse, prevents the exercise of the culinary art. In the night of the 21st to 22d it overturned our cabin, and we were obliged to work until morning to restore it again. Imagine how delightful it must have been to work in the open air at a temperature two degrees below zero, while a tempest was constantly blowing clouds of pulverized ice in our faces."† But every day and night was not like this. Gayety and intellectual enjoyment often reigned under the tent on the glacier of the Aar. These expeditions were continued until 1845.

The greatest success crowned these persevering efforts. The ascents made by the Neuchâtel naturalists and their establishment upon the glacier were widely known. Nothing similar had been undertaken since the explorations of de Saussure on Mont Blanc. The Genevese savant was too early in his efforts to have many imitators. But an excursion to Zermat, the ascent of the Jungfrau and of the Schreckhorn gave an impetus to mountain excursions, which began from that time to be popular. In the mean time our naturalists were studying seriously the constitution of the glaciers and the phenomena connected with them,

*A whirlwind of snow, called so in the Oberland.

†Letter to M. A. Favre, August 1, 1842.

and notwithstanding their want of familiarity with the laws of physics, the subject was so new that they rapidly acquired valuable information.

On his return from each expedition Agassiz published the results of his researches. His object was not only to give an account of his observations, but to disseminate the theory of which he had become the defender and promoter. Numerous memoirs upon present and ancient glaciers of Switzerland, upon the glacial theory, upon the erratic blocks of the Jura, bear the date of these years. Large works which appeared later at Neuchâtel and at Paris contained the results of his studies.* These works revealed numerous phenomena then completely unknown, made the knowledge of the glaciers popular throughout the world, and gave a decisive impulse to this kind of study.

Many years later Agassiz, while navigating the river Amazon, gave the following illustration of the aspect presented by the glacial period: "There is a phenomenon not uncommon in the autumn in Switzerland which may help us to reconstruct this wonderful picture. Sometimes in a September morning the whole plain of Switzerland is filled with vapor, which, when its pure white undulating surface is seen from the higher summits of the Jura, looks like a snow-covered *sea of ice*, appearing to descend from the peaks of the Alps, and extending toward the Jura, while from all the tributary valleys similar masses pour down to meet it."†

In 1840 Agassiz went to Great Britain to seek there for traces of ancient glaciers. He had no trouble in finding them both in England and in Scotland. His journey through the country was a veritable triumph, a series of ovations.

This period of incessant activity, during which the scientific corps of Neuchâtel became so honorably distinguished, was not, however, for Agassiz a period of undisturbed happiness.

To meet the expenses of his extensive publications, his travels, his expeditions to the glaciers, a large fortune was necessary, and this Agassiz did not possess. The sums he owed to the generosity of the King of Prussia, and which at that time had taken the form of a regular pension, were not at all sufficient for his needs, and rapidly disappeared in the gulf of his expenses. Still the fire of his activity his labors, his expeditions, continued; but the situation at last became so critical that he was forced to bring order into his affairs. Some letters of this time show the serious embarrassment these difficulties occasioned him. "I am frightened at the approach of a new year, the time for the settlement of accounts in Neuchâtel, and I work like a madman to be able to meet my indebtedness. If God preserves my health I hope, after one or two years of continued labor, if I moderate my expenses, and particularly if I abstain from publishing anything more on my own account, to

*Agassiz. *Études sur les glaciers, avec un atlas de* 32 *pl.* Neuchâtel, 1840. *Nouvelles études et experiences sur les glaciers actuels.* Paris, 1847.

†A Journey in Brazil, by Professor and Mrs. Louis Agassiz, Boston, 1868, chapter iii, p. 116.

settle my affairs completely, but for the time I am horribly cramped, I must say almost paralyzed; but it is my own fault, and I must bear patiently the consequences until I can succeed in getting myself afloat again." "My great regret in the present condition of my affairs is that I am obliged to employ a portion of my time with matters I ought not to have neglected, and which occupy me now much more than if I had always attended to them, and then I am obliged to retard some of the publications I greatly desired to make next, but which it would be imprudent for me to undertake at present, for I should reproduce the embarrassment from which I only just commence to be relieved if I did not conduct all my enterprises with the utmost circumspection." "My life," he writes again, "is now a vortex, in which the best part of my nature is hardly conscious of its existence, so numerous and pressing are the exterior exigencies from which I suffer."

But how many grand ideas, how many admirable works, would have been lost to science if the young savant had not been willing in his publications to dispense with the economy he would have been obliged to exercise to keep within his moderate pay as a professor.

Agassiz was devoted above all things to science; devoted without reserve; and he had always great talent in making others share his enthusiasm. Bringing into contribution the talents of some, the purses of others, adding all his own resources, modest it is true, but also all his time and his genius, he attained a result evident now to every one. A letter he wrote to Professor Silliman, when about to embark for America, shows how entirely he gave himself to science. "In order to provide for the extra expense, I shall be obliged to live very economically and in a manner little in accordance with the royal munificence which has furnished the means of making this journey." And, again, "My sphere is entirely circumscribed by the scientific world, and all my ambition is limited to being useful to the branch of science I particularly cultivate. With all this I am no misanthrope; but I learned early that where one has no fortune, one cannot serve science and at the same time live in the world. If I have been able to produce numerous expensive publications, it has been only by following this system of economy and voluntary seclusion; and the results which I have obtained thus far have rewarded me so well for the privations which I have suffered, that I have no temptation to adopt another style of life, even should I hereafter, and especially in your country, suffer more trouble than I have had to sustain in my own."*

Discord, however, had penetrated the scientific coterie of Neuchâtel. Enthusiastic over new ideas, Agassiz entered into them with ardor; when he found them just he developed them and diffused them. Older than his colleagues, more enterprising, already well known in the scientific world, he published under his own name the work done in his

*Letter to Professor Silliman, October 20, 1845. American Journal of Science: 1874. Vol. vii, pp. 78, 79.

laboratories, giving to the names of his collaborators a secondary place. It was he who inspired the work, who collected the material, who bore the expense of the publication. But the aids soon demanded the credit they considered their due; hence arose dissatisfaction and disagreements, which continued to increase until the union was dissolved. Mr. Vogt was the first to leave the association in order to go to Paris; Mr. Desor continued to labor on Agassiz's works, even after the departure of the latter for America. He later joined the savant there, but he afterward returned to Europe. One cannot but regret that these personal questions should have interfered so soon with the happy scientific labor of that time.

Agassiz passed the winter of 1845–'46 at Paris. The vast collections, public and private, of that city were generously placed at his disposal, and enabled him to complete, with the valuable assistance of M. Desor, his researches upon the Echinoderms. Those of Alcide d'Orbigny, of Deshayes, of Mechelin, of Graves, of Alexander Brongniart, of de Verneuil were in turn examined. The gallery of the museum containing the Echinoidea was reserved for him and closed to the public, and hither were brought in succession all the cases and barrels containing Echinoids. Considerable material, derived from the scientific explorations of Baudin, of Freycinet, of Captain Duperré, passed also through his hands. All these documents were used in the publication of the *Catalogue raisonné*. According to the classification adopted, the Echinoderms are subdivided into three orders: The Stelleroids which include the Asteroids, the Ophiuroids and the Crinoids, radiated animals, either free or fixed, and of which the body is furnished with rays. The Echinoids, or sea-urchins, with a body globular and covered with regular plates, and the Holothurioids, of which the body is coreaceous, or leathery, and elongated. He divided the Echinoids into four families: Cidarida, Clypeastroidea, Cassidulidea, and Spatangoida. In his preceding works he deduced from the structure of these animals and their successive appearance important consequences for the general history of creation.

He sought at the same time to propagate the glacial theory, which still encountered in the ranks of French science a lively opposition; but he discussed it only in private conversation. This subject did not excite much interest in the scientific public, who knew little of the mountains, and the heads of science entertained contrary ideas.

This same year Agassiz, whose reputation was already far extended, was called to Boston, in America, by Mr. Lowell, director of the Lowell Institute, to give some lectures. He was also, thanks to Humboldt, charged by the King of Prussia with a scientific commission in that country. He went to England in the summer of 1846, and sailed for Boston in the month of September.

III.

Arrived in America, where his reputation had preceded him, he did not lack encouragement and support in that country, where great ideas so easily find an enthusiastic public and generous protectors. The first of the lectures he gave in Boston was repeated eight times to an audience always new and always eager to hear. The success of the subsequent lectures was equal to that of the first. From the very outset the learned naturalist acquired great popularity. He was surrounded, fêted, made much of, and was charmed by the zeal manifested on all sides for natural history. The first part of his sojourn was passed in giving single and courses of lectures. Embryology and the glaciers were his most frequent subjects.

After his debut at Boston he lectured successively at New York, Albany, New Haven, and Charleston, where he passed the winter of 1847–'48. He at the same time determined to profit by the resources which surrounded him, and immediately commenced to make collections. Everything about him was new, and he had only to stretch out his hands in order to fill them. A generous American, Mr. Abbott Lawrence, convinced of the importance of retaining a man of such value in the country, offered in 1847 to create a chair for him of zoology and geology in Harvard College, Cambridge, if he would remain. Agassiz, who had come to the United States with very favorable anticipations, far surpassed by the welcome he had received, did not hesitate to accept the proposition. He comprehended that his reputation would give him promptly a power and means of action which he could never acquire in Europe. Establishment in this country would also put an end to the rivalries, the cares of all sorts, to which he was a prey in Neuchâtel. He would be able to consecrate to science his time and his strength without being obliged for want of money to restrict or retard his publications. He abandoned, then, without regret the modest theater where he had first distinguished himself, and commenced an entirely new career, in which he was to find resources even beyond his brightest dreams.

He took possession, upon his return from Charleston, of the chair of natural history, which had been offered to him. His dwelling was at Cambridge, in Oxford street. Count Frank de Pourtales, Professors Desor, Marcou, Guyot, Lesquereux, and his draughtsman, Burckardt, who since his sojourn at Munich had always worked for him, now joined him. Several of these naturalists lived for some time with him. He received them bounteously, and aided them with his influence and his purse, at that time better filled than when he was in Neuchâtel. Soon he sent for his son Alexander, whose taste for natural history was a great joy to him. He passed the first four months of the year 1849 at Philadelphia, where he gave courses of lectures, and in the winter of 1849–'50 he married Miss Elizabeth Cary, of Boston, a lady of great intelligence, who became the inseparable companion of his travels and of his work.

The exploration of America was a vast field opened to him, and he devoted to this work a very important part of his time. In 1848 he undertook the charge of a scientific expedition to Lake Superior. Seventeen persons started on this exploration in a country the geography and natural history of which were still very little known. The zoology, the botany, the general character of the country and the indigenous inhabitants, the influence even of the progress of civilization upon the aspect of the country, upon the character of the fauna and of the flora, all were observed, recorded, discussed; nothing of importance escaped the eager and masterly eye of the chief of the expedition.*

The history of the journey was made by Mr. Cabot; the shells, insects, and birds collected were studied by various collaborators. Agassiz devoted especial attention to the general characteristics of the vegetation, in order that he might compare it with that of the Jura and the Alps; to the fishes, the study of which wherever he went always captivated him; to some new reptiles, and finally to the phenomena of erratic bowlders in this region, which his knowledge of the glacial district of Europe permitted him to prove belonged to a remarkable extension of the same system.

The Americans have devoted for a long time especial attention to the study of the shores of their continent. The department of the government occupied with what is called the United States Coast Survey is now known all over the world on account of the great importance of the work it has accomplished. It united to a geographical knowledge of the coast a scientific study of the neighboring region, often pursued under great difficulties. Agassiz from the first was interested in this species of investigation. In 1850 he was commissioned by Dr. Bache, director of the survey, to study the coral reefs of Florida. He examined upon the spot the development of the Polyp, which had created around this peninsula four concentric banks, the formation of which he found had been successive. According to the mode of increase of these animals, he could calculate safely within the limits of truth that these reefs had been at least thirty thousand years in forming. The outer reef, still in process of development, is constituted of the living coral. The animals belong to various types, each of which is limited to a certain depth beyond which it cannot exist. The deepest are the Astræans, next the Meandrines; at the surface are the Madrepores, not more than two or three yards below the surface of the water and covering vast spaces with their beautiful growth. Other animals become attracted to the coral branches. The sea breaks off the coral and throws the fragments upon the reef, which is little by little covered with soil,

* Louis Agassiz. "Lake Superior, its physical character, vegetation, and animals, compared with those of other and similar regions. 1850."

and rises at last above the water. The winds then bring to it seeds, and plants are developed. Thus appears an island separated by a small lagoon from the mainland, to which it will soon be united. Florida has been entirely formed in this way by successive creations. The time required to produce this peninsula, according to Agassiz, must have been more than two hundred thousand years.

At the same time that Agassiz undertook to direct these expeditions he desired to make known the results of his researches and the labors undertaken in his laboratories. The great collections he amassed attracted his attention to all branches of the animal kingdom. The Vertebrates, the Mollusks, the Articulates, the Radiates, the relations of these branches to each other, their mode of appearance and development, were for him an incessant source of new observations, published in numerous articles and memoirs.

In 1857, he gave to the public the plan of a work to be called *Contributions to the Natural History of the United States.* The popularity of the professor was at that time so great that he immediately obtained more than 2,500 subscribers. Four volumes of this work appeared in succession.*

The first monograph comprehended a complete study of the Chelonians, their anatomy, their distribution in the actual world and in geological history, the description of American genera and species, and the embryology of the turtle. The second, in the preparation of which Mr. Clark rendered active assistance, is upon the Acalephs, which form with the Polyps and the Echinoderms the class Radiata; they are divided into Ctenophores, Discophores, and Siphonophores. Mr. Sonrel was the artist of the magnificent plates which accompanied these two volumes. A complete *résumé* of the ideas and the principles of Agassiz relative to the classification of the animal kingdom, serves as an introduction to these monographs.

"In the beginning of this chapter," he writes, "I have already stated that classification seems to me to rest upon too narrow a foundation when it is chiefly based upon structure. Animals are linked together as closely by their mode of development, by their relative standing in their respective classes, by the order in which they have made their appearance upon earth, by their geographical distribution, and generally by their connection with the world in which they live, as by their anatomy. All these relations should, therefore, be fully expressed in a natural classification; and though structure furnishes the most direct indication of some of these relations, always appreciable under every

*Contributions to the Natural History of the United States; in quarto volumes, with numerous plates. Volume I, Essay on Classification; North American Testudinata. 1857. Volume II, Embryology of the Turtle. 1857. Volumes III and IV, Acalephs in general, Ctenophoræ, Discophoræ, Hydroidæ, Homologies of the Radiata. 1860–1862. The introduction to the first volume, "An Essay on Classification," was republished under the author's direction, at London, in 1859, in 1 vol. 8vo., pp. 381.

circumstance, other considerations should not be neglected which may complete our insight into the general plan of creation." *

In this point of view Agassiz had already perceived through his study of fossil fishes the importance of embryology. He had for the first time propounded the theory that the animals of our period in their embryonic condition resemble the ancient representatives of the same type who lived in anterior geological ages.

Classification, based upon these considerations, will no longer be a system invented by such or such a naturalist, but will result strictly from facts observed in nature. It will be proved, for example, that an insect in various degrees of its development resembles successively types of various classes of the branches of the Articulata, and that it assumes the character of a perfect insect only after it has achieved its metamorphosis. "When we study the gradual development of the insect * * * we have a simple, natural scale by which to estimate the comparative rank of these animals. Since we cannot suppose that there is a retrograde movement in the development of any animal, we must believe that the insect stands highest (compared with crustacea and other articulates), and our classification in this instance is dictated by nature herself." †

"It may therefore be considered as a general fact, very likely to be more fully illustrated as investigations cover a wider ground, that the phases of embryonic development of all living animals correspond to the order of succession of their extinct representatives in past geological times. As far as this goes the oldest representatives of every class may then be considered as embryonic types of their respective orders or families among the living." ‡

The class of Echinoderms furnishes a remarkable example. It is thus that the embryonic phases of the European Comatula correspond with the principal forms of the Crinoids which characterize the successive geological periods; Cistoids of paleozoic rocks; Platycrinoids of the carboniferous period; Pentacrinoids of the freestone and the oolite. Analogous facts are found in the families of the Asteroids and the Echinoids. The Trilobites are the embryonic type of the Entomostracans; the Decapods of the oolite that of our crabs; the heterocercal Ganoids that of the Lepidistes.

By the side of these *embryonic* types Agassiz recognized *prophetic* types. "Embryonic types exemplify only the peculiarities of development of the higher representatives of their own types; while prophetic types exemplify structural combinations observed at a later period in two or several distinct types." One of the most striking examples he cites is that of the sauroid fishes. "These fishes, which have preceded the appearance of reptiles, present a combination of ichthyic and reptilian

* An Essay on Classification. 8vo., London., 1859. Chap. i, sec. 32, pp. 205, 206.

† A journey in Brazil. Boston, 1868, chap. i, p. 21.

‡ Essay on Classification, chap. i, sec. 25, p. 174.

characters not to be found in the true members of this class, which form its bulk at present."

The succession of organized beings in the course of time should also serve as a principle of classification. Thus in arranging, as many botanists do, the Gymnosperms among the Dicotyledons, we find no relation between the hierarchical series of the living plants and their mode of appearance. If we make of the Gymnosperms an isolated group, intermediate between the Cryptogams and the Angiosperms, a classification which corresponds with their principal characteristics, we find immediately an intimate correlation between the hierarchal series of these plants, which commence with the Cryptogams and continue with the Gymnosperms, the Monocotyledons, and Dicotyledons, and their successive appearance.

"I confess," said Agassiz, "that this question as to the nature and foundation of our scientific classifications appears to me to have the deepest importance; an importance far greater, indeed, than is usually attached to it. If it can be proved that man has not invented but only traced this systematic arrangement in nature; that these relations and proportions which exist throughout the animal and vegetable world have an intellectual, an ideal, connection in the mind of the Creator; that this plan of creation, which so commends itself to our highest wisdom, has not grown out of the necessary action of physical laws, but was the free conception of the Almighty Intellect, matured in His thought before it was manifested in tangible external forms; if, in short, we can prove *premeditation* prior to the act of creation, we have done once and forever with the desolate theory which refers us to the laws of matter as accounting for all the wonders of the universe, and leaves us with no God but the monotonous unvarying action of physical forces, binding all things to their inevitable destiny. * * *

"To me it appears indisputable that this order and arrangement of our studies are based upon the natural primitive relations of animal life; those systems to which we have given the names of the great leaders of our science who first proposed them, being in truth but translations into human language of the thoughts of the Creator. And if this is indeed so, do we not find in this adaptability of the human intellect to the facts of creation, by which we become instinctively and—as I have said—unconsciously the translators of the thoughts of God, the most conclusive proof of our affinity with the Divine mind? And is not this intellectual and spiritual connection with the Almighty worthy of our deepest consideration? If there is any truth in the belief that man is made in the image of God, it is surely not amiss for the philosopher to endeavor by the study of his own mental operations to comprehend the workings of the Divine Reason, learning from the nature of his own mind better to understand the Infinite Intellect from which it is derived."†

*Essay on classification, Chap. i, sec. 26, p. 177.

†Essay on Classification, chap. i, sec. 1, pp. 10 and 9.

I have given this long quotation, because it shows clearly the elevated philosophical and religious point of view from which Agassiz regarded the history of creation.

It is seen by the examples given what importance he attached to paleontology. He endeavored to show that from the ancient geological periods the number and diversity of animated beings was as great as it is to-day. Certain rocks are formed entirely of the *débris* of organized beings. The coral reefs of the tertiary, secondary, and even primary periods are in no wise inferior to the present reefs.* The coal-beds of the carboniferous period exhibit a vegetation richer than our tropical flora. These myriads of beings which have ceased to exist he regarded as the manifestation of the divine thought, which regulated their mode of appearance and succession. "There were at various intervals during the successive geological ages periods of creation, all the species of animals and of plants created at each period having lasted for a given time in order to be replaced successively by others." The present creation is, according to his view, one of these phases, and he believed that all the animals in it appeared simultaneously.

Agassiz always remained faithful to this theory, which had many adherents at the time he advocated it. Science has made great advances since that period. The progress of paleontology, to which he contributed so largely, as well as that of zoological and botanical geography, demonstrates by the fullest evidence that the animated world which peoples the surface of the globe could not have issued complete and simultaneously from the hands of the Creator, for in the midst of new types there exist offshoots from numerous groups, whose great development took place in the anterior geological periods, while other types have acquired in the present epoch a force and extension they never had before, although their successive increase was indicated in the later geological periods. The present ferns are only the representatives, greatly diminished in size, of that large group of Cryptogams which at the carboniferous period clothed the entire world with their colossal vegetation, and which since then have been constantly diminishing.

The traveler who encounters isolated in the mountains of China the singular conifer called the *Ginho biloba* will not hesitate to consider this type, unique in the present creation, as the last descendant of the Ginho which, at the secondary period, covered with a great number of species all the ancient continent. The zoologist who finds in the rivers of Australia the *Lepidosteus osseus*, the last representative not only of a genus but of an entire order of fishes, that of the Ganoids, cannot fail to recognize in this type the remains of an extinct race. The Marsupials of the same country, the Edentates of South America, and a hundred other examples furnish us to day-with the proof that the actual world is only the regular normal continuation of anterior periods. In spite of the embryological theories of which Agassiz was the author, and which it

*American Journal of Science, 1854, vol. xvii, pp. 309–324.

would seem must necessarily have led him to the idea of evolution, he always remained an absolute partisan of the hypothesis of successive creations, and he may be regarded as the chief of the opposition to the theory of development.

The fact that the most distinct types exist simultaneously in identical circumstances, and that we find identical types in the most different circumstances, the entire development of the animal kingdom, the harmony in its most diverse parts, its present and past distribution upon the continents and in the sea, furnished him unceasingly with new arguments to combat this theory and to defend that of the individuality and the constancy of species.

If it is evident that the flora and fauna are renewed a great number of times on the surface of the globe, it has never been proved, according to him, that the species were changed during one of those periods. The observations made of the times in which we live, indicate that they remained invariable during each period. This is demonstrated by the plants and animals found in the tombs of Egypt and the fauna of the coral reefs of Florida. Daily discoveries contradict strongly the opinion that inferior beings first appeared upon the earth, and that types more and more elevated were manifested until the advent of man. On the contrary, representatives of numerous families of the four great branches of the animal kingdom, Radiates, Mollusks, Articulates, and Vertebrates, lived simultaneously from the most ancient periods. The Vertebrates alone have not yet been found in the first deposits, but they appeared in immense numbers before the end of the first period. These branches, which manifest in their structure a complete independence, have traversed side by side all the series of geological ages up to the present time. The first three are even represented from the beginning by numerous types of their different classes, and the character of the branches of the classes of the families have always been as distinct as to-day. "Until the facts of nature are shown to have been mistaken by those who have collected them," said Agassiz, "and that they have a different meaning from that now generally assigned to them, I shall consider the transmutation theory as a scientific mistake, untrue in its facts, unscientific in its method, and mischievous in its tendency."*

Agassiz preferred greatly direct observation of nature to theoretic research, and he found more than any other naturalist opportunities for this study in his numerous voyages and in the immense material he collected. In a country so rich, so varied in climate and conditions, and also so new, his collections rapidly accumulated; he sold them in 1852 to Harvard College. A building which had been put up to receive them proved to be too small. The University of Cambridge, aided by a public subscription and by the State of Massachusetts, caused to be erected the first wing of a large edifice, which was to bear the name of the Museum of Comparative Zoology. Mr. Fr. C. Gray bequeathed $50,000 to

* On the Origin of Species. Am. Journal of Science. 1860. Vol. xxx, p. 154.

found this establishment. The first stone was laid on the 14th of June, 1859, and in December of the same year the building was sufficiently advanced to commence the installation of the collections.

From that time Agassiz had but one aim, the increase and organization of this museum. "His activity, researches, diplomacy, resources," wrote to us one of his friends who saw him at work, "are something prodigious. He spared nothing where his museum was concerned, gave public lectures, resorted to all kinds of devices to promote its interests: he put under contribution all his friends and acquaintances; he spoke of nothing, saw nothing, but his museum; it became his one idea." The gifts of natural objects and of money poured in from all sides. The State and private individuals rivaled each other in generous assistance of this great work which Agassiz had succeeded in making a national affair, and in a few years the pecuniary subsidies amounted to the sum of $470,000. During the years 1872 and 1873 alone the museum received besides its annual supplies gifts equal to about $170,000.

The vast learning of Agassiz, his amiability, his benevolence, his affable gaiety, his enthusiasm for everything relating to science, and his personal disinterestedness, everywhere created for him friends who contributed to the increase of his museum. Never had any one so many. His language, winning and often rising even in English to true eloquence, captivated his audiences and attracted the crowds he loved to teach. He was in communication with all the sea-captains, who made collections for him in their distant expeditions. When he was on a voyage everybody was at his disposal, and more than once the inhabitants of the distant countries he visited made journeys of considerable extent in order to procure some rare animals for him only for the pleasure of seeing his joy, his astonishment, and his gratitude, which were always very warmly and openly expressed.

All parts of America were explored. The Emperor of Brazil, whose interest in science has never flagged, sent him rich collections. The soundings made along the coast of America by the United States Coast Survey, under the direction of Mr. de Pourtalés, and especially the voyage to the valley of the Amazon and the expedition of the Hassler, added greatly to these zoological treasures. In 1863, that is to say, before the expedition to Brazil, the museum already contained 6,000 species of fish, represented by 100,000 specimens. It is not, like most collections of natural history, a mass of material disposed in a purely zoological order. Its organization is based upon the principles of classification we have described; and we find in it several distinct series. In the first the animals are classed in such a manner that one can study their natural associations, their zoological relations, the general characteristics of the genera and of the classes, their skeletons, and other anatomical peculiarities. A second series represents the fauna of each region, the geographical distribution of living beings upon the surface of the globe and their various associations, upon each continent. The fossil animals are arranged so as to show at the same time their order of succession in the different epochs and their relation with the existing animals. This plan is completed by a third series devoted to the study of the various phases of development of animals from the embryonic to the adult condition. This museum, then, is destined to be an exposition of the history of creation, as complete as it is possible for it to be under the present state of our knowledge. Its organization absorbed more and more the time and energy of Agassiz. No other scientific establishment has aspired to a similar undertaking.

When it came to the recent creation, it increased so rapidly that in 1872, in his last report of the progress of the establishment, Agassiz could say that he was "in possession of the most beautiful collections in the world, not excepting the oldest and largest museums of Europe." What increased still more their value, was the zoological and paleontological labors to which these collections gave rise. Naturalists of great distinction, Mr. Alexander Agassiz, our compatriots Messrs. Alexander de Pourtalés, Lesquereux, and some American scientists, Messrs. Lyman, Hyatt, &c., described these treasures in works illustrated with magnificent plates.

A voyage which Agassiz made to Europe in 1859 interrupted for some time his incessant occupations. He was not forgotten in the Old World, the scene of his first successes. The most brilliant offers were in several instances made to him to induce him to remain, but he had in America too many resources of all kinds to make him able or willing to abandon his adopted country; his only ambition was for science, and he always continued faithful to the direction of his museum. He was naturalized as an American citizen in 1862.

The numerous labors he directed at last affected his robust health. During the winter of 1864-'65 the physicians ordered absolute repose and a change of climate. But this rest proved to be as profitable to science as the continuations of the works he had undertaken. After some hesitation Brazil was selected as the destination of his voyage. He had been for a long time attracted toward this country, to which his first zoological researches had turned his attention. "Toward Brazil I was drawn by a life-long desire. After the death of Spix, when a student of twenty years of age, I had been employed by Martius to describe the fishes they had brought back with them from their celebrated Brazilian journey. From that time, the wish to study this fauna in the regions where it belongs had been an ever-recurring thought with me; a scheme deferred for want of opportunity, but never quite forgotten."*

In order to render this voyage of real use, in order that he might not return to the United States "rich in pleasant memories but without any scientific results," resources were necessary far beyond those required for his personal expenses. Here, as on so many other occasions of his life, bountiful means were voluntarily provided. Mr. Nathaniel Thayer

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*A journey in Brazil. (Preface, p. v.)

offered to defray the expenses of the expedition, and authorized him to take with him, as assistants, six naturalists. The Emperor of Brazil, the Secretary of the Navy of the United States, the president of the Pacific Mail Steamship Company, each contributed in large measure to the success of this expedition, which had been joined by some distinguished naturalists as voluntary recruits. On the 1st of April, 1865, Agassiz embarked, taking with him Mrs. Agassiz, who kept the journal; her husband communicated to her the scientific results as they were obtained, and thus was composed the book known under the name of "A Journey to Brazil." We refer to this volume any of our readers who desire to follow the American savans along the borders of the Amazon and explore with them the vast basin they undertook to study.

Agassiz, during this voyage, made immense collections. These have already been, in part, studied and described, and will give rise to works which will make better known to us the fauna of the extraordinary region. He observed, also, many general facts of natural history. The account of the expedition manifests the great talent he possessed of noting every peculiarity offered to his observation in the zoological character of the animals he discovered, in the ichthyological fauna of the Amazon, in the geographical distribution of the terrestrial and aquatic animals, and in the physical and geological characteristics of the great valley he traversed.

One of the points which fixed his attention and to which he constantly refers in the history of the voyage, is the nature and the distribution of the *drift* of this region. This deposit, which is of great thickness and immense extent, for it is estimated to be some thousand miles in length and six or seven hundred in width, could not have been formed by the sea, since there were no traces found of marine shells. It is, then, a fresh-water deposit. If a lake had occupied this vast space the basin must have been closed; otherwise, this material would have been carried into the sea. Agassiz attributed this phenomenon to the ancient extension of the glaciers. An immense glacier, according to him, descended from the Cordilleras, augmented by tributaries from Guiana and from Brazil, and covered the valley of the Amazon. It accumulated at its lower edge a moraine of colossal dimensions, forming thus a gigantic embankment, which bars the mouth of the basin.

It is true that polished and scratched surfaces are not found; the rocks are too soft to have retained such traces, but the rounded rocks Agassiz observed in some localities, the blocks of the Ereré, the nature of the deposit in the valley, the character of which is analogous to that of the material accumulated under the glaciers; the resemblance of the upper formation of this country to the *drift* of Rio, the glacial origin of which seemed to him beyond a doubt; the fact that the basin of fresh water must have been closed on the side of the ocean by a powerful barrier, appeared to him sufficient arguments to establish the existence of this glacial period. Later there was a rupture in the exterior embankment; the lake was emptied, while the moraine, beaten by the sea and carried away by the flowing waters, disappeared, as was also the case in great part with the ground upon which it rested; for the violence and the rapidity with which the sea eats into the shores of this region is extreme, and a strip of hundreds of miles in width has already been carried away. *

Such is, in a few words, the theory of Agassiz of the ancient glaciers of Brazil. This is not the place to discuss its claims; it was attacked on all sides, and has now few defenders.

In his latter years Agassiz, overburdened with his occupations, abandoned special research; the organization of his museum, his public courses of lectures, his immense correspondence, were too much for his strength, and his health gradually failed. In 1869 he became seriously ill. He had hardly recovered before he was at work again. He accompanied Count Pourtalés on one of the expeditions this zoologist made in the year 1867, to study the submarine relief, the currents, and the marine fauna of the coasts of America. These explorations, in which each sounding gave rise, so to speak, to a discovery, captivated him extremely, and he soon conceived the idea of extending this kind of research. In 1871 he joined an expedition organized by the Government of the United States for the exploration of the shores of America, the study of the Gulf Stream, the temperature of the water, and the marine animals. He sailed in the Hassler, and visited in this vessel the sea of the Antilles and the shores of America as far as San Francisco, doubling Cape Horn. A letter he wrote to Professor Pierce before starting, in which he set forth the results he hoped to obtain, drew upon this expedition the attention of all the scientific world. He hoped to find living at the bottom of the sea a large number of the types known only by fossil representatives, and thus connect the actual with anterior creations.

Soundings were made at first at great depths, but the apparatus was in a bad condition, and on the coast of Chili this kind of research had to be abandoned. Agassiz contented himself with the coast animals and the fishes, which he collected by thousands. In every port the deck of the vessel was covered with animals brought by the natives. The singular fauna of the Gallapagos Islands were collected with the greatest care, and Agassiz was able, among others, to procure numerous shells of two species of reptiles of the genus *Amblyrynchus*, the structure of which recalled that of these animals in the secondary period. Some idea may be formed of the collections made in this voyage, by the fact that the quantity of alcohol used to preserve the animals was about 3,500 gallons. He came back to Cambridge by the Pacific Railroad.

Immediately on his return he formed the project of establishing on the sea-shore a school for zoological research. As soon as the idea was conceived, an American, Mr. Anderson, gave him in 1871 a small island in Buzzard's Bay, the island of Penikese, and a considerable sum to assist

* Journey in Brazil, Chap. xiii, pp. 419–436; Atlantic Monthly, 1866, pp. 49, 150.

in carrying out his design. The illustrious naturalist immediately profited by these resources. He constructed large laboratories provided with aquaria and other arrangements necessary for this kind of research. The upper story of the building contained fifty-eight rooms for the lodging of the naturalists. Every effort was made to hasten the execution of the plan. The consequent increase of fatigue exhausted him. On the 2d of December, 1873, he gave a public address to the Agricultural Association of Massachusetts. He was in his laboratory for several days after, but was attacked on the 6th of December by weakness, which forced him to return home. He went to his bed, which he never left again, and expired on the 14th of December of a paralysis of the organs of respiration.

The Academy of Sciences, of Paris, had a few months before nominated him foreign associate member.

"For a long time," wrote Professor Silliman, who had been one of his best friends since his arrival in the country, "have we dreaded the sad event which we now record. For many years the splendid physique of Agassiz manifested signs that his prodigious labors were overcoming his elasticity. His herculean strength, which made fatigue of body or mind unknown to him, yielded to the severer tax of the American climate and the incessant growing demands upon him from every source. His life and strength were renewed by his long voyage to San Francisco in the Hassler; but both he and his friends recognized the fact that to labor with his former activity was impossible and forbidden. Yet to live, was for him unavoidably to labor; and to die in the harness rather than to live after the power to serve his fellow-men was passed—his aspiration."*

The death of the great naturalist, to whom this noble sentiment could be justly attributed, was a national calamity. An immense cortege formed by deputations from several cities, the Vice-President of the United States, the authorities of the State of Massachusetts, delegates from universities, academies, and learned societies, his numerous pupils and assistants, and a large concourse of citizens accompanied Agassiz to his last home.

A bowlder from the glacier of the Aar, upon which is engraved his name, serves as a monument to him and recalls to those who visit it his native country and one of the great interests of his life.

The prodigious capacity of Agassiz, his exceptional talent for observation, the facility with which he made himself familiar with all questions and with which he attacked the most diverse subjects, the great intellectual movement he developed wherever he lived, the value of his own researches, have made his name one of the greatest in contemporary science. He has been the object, both while living and even after his death, of violent and sometimes coarse attacks; calumny has not spared him. But in every case it is not he who has been most injured. Un-

*Amer. Jour. Science, 1874, vol. vii, p. 80.

doubtedly, several of the ideas he put in circulation have been dropped, several of his theories have been abandoned, but the discussions they produced have been a fruitful source of progress. The temple of knowledge is not raised by a single effort, and it is the clashing of ideas which produces light. The work he executed in the field of zoology and of paleontology is of very high importance. He possessed the double merit of accomplishing great things himself, and of knowing how to make science popular without diminishing its prestige. Everywhere he found friends and supporters. In Switzerland, in Germany, in England, in America, in every country where he took up his abode he made himself the center of the scientific movement and succeeded in interesting the public. His sojourn in Neuchâtel excited in that city an impulse the happy influence of which is felt even to this day. Although when he first went to the United States there existed scientific culture in that country, and many distinguished observers, to Agassiz must be attributed the diffusion of a new enthusiasm for the sciences and much of the success with which they are now cultivated. This result is not due to chance, but to the noble and legitimate influence exercised by the superior intelligence of the savant, and the amiable qualities of the man.

HENRY AND THE TELEGRAPH.

By William B. Taylor.

"Yet though thy purer spirit did not need
The vulgar guerdon of a brief renown,
Some little meed at least—some little meed
Our age may yield to thy more lasting crown."

In the impulsive tide of popular applause which follows the consummation of great enterprises, or the material advancement from new conquests of natural law, the labors and merits of those who patiently laid the deep and broad foundations of these successes, or who with rarest diligence, sagacity, and skill, made such successes practicable, are usually whelmed; and—save by the scientific student, are mostly forgotten and ignored. And this result is the more assured by reason of the entire self-unconsciousness and devotion with which the higher work of original research is conducted, with no disturbing thought on the part of the investigator, of reaping immediate advantage or reward from the bestowal of the new discovery.

"For praise is his who builds for his own age;
But he who builds for time, must look to time for wage."*

That the award of time respecting Henry's true relation to the telegraph will be discriminating and just, may be confidently anticipated, since the materials and data for an accurate judgment are already matter of enduring record.† In attempting here to briefly review this record, justice will best be done to Henry's fame by rendering full justice to Henry's predecessors.

The Growth of the Electric Telegraph.—"The electric telegraph had properly speaking, *no inventor*. It grew up little by little, each inventor adding his little to advance it toward perfection."‡ These words of soberness and truth are little apprehended by the multitude; who blind alike to the beginnings and to the growths of great ideas, contemn the

* Prof. Grant Allen.

†In the spirit of Kepler (though with less of self-assertion), Henry, with a modest estimate of his own contributions to science, while evincing a remarkable indifference to popularity, yet with the quiet confidence of a clear and impartial judgment, declared "I was content that my published researches should remain as material for the history of science, and be pronounced upon according to their true value by the scientific world."—(*Smithsonian Report* for 1857, p. 87.)

‡ *The Electric Telegraph.* By Robert Sabine. 8vo. London, 1867, part i, chap. iv, sect. 39, p. 40.

discoverer while they deify the artisan. When Galvani about a century ago (1786) first opened slightly the door to one of nature's marvels, that large community ever distinguished by the vigor of its common sense and the practical solidity of its judgment, asked with ready instinct the wise and ancient question, "What is the *use* of it?" And a majority of those who recognized the experimenter's appearance on the streets of Bologna, pointed him out as the "frog philosopher." Their descendants and representatives at the present day have neither lost—nor gained in wit.*

It is proposed to notice the development of the electric telegraph somewhat at length, in order to exhibit more clearly the precise nature and value of Henry's contribution to its practical establishment and success. This survey naturally divides itself into a chronological review of the successive though overlapping applications—of frictional or mechanical electricity (first suggested by Franklin? or by Lesage? about the middle of the last century); † of galvanism or chemical electricity (first suggested by Sœmmering in 1808); and of galvano-magnetism (first suggested by Ampère in 1820). ‡

Among the numerous flights of imagination by which genius has frequently anticipated the achievements of her more deliberate and cautious sister—earth-walking reason, none is perhaps more striking than the romantic conception by Famianus Strada, of Rome, in the early part of the seventeenth century, of an intercourse maintained between separated friends by means of two sympathetic magnetic compasses, whereby the indications on the dial given by one, were instantly made visible to the other. §

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* On the value of abstract science, see "Supplement," NOTE A.

† Mr. Stephen Gray, in a letter to Dr. Cromwell Mortimer, secretary of the Royal Society of London, dated February 8, 1731, recited among numerous electrical experiments, the passage of sparks and the excitation of an electroscope, effected through 293 feet of wire suspended by silk, in 1729; through 666 feet on July 3 of that year; a week or two later, through 765 feet; and in August, 1730, through 886 feet of wire. (*Phil. Trans. R. S.* 1731, vol. xxxvii, No. 417, pp. 29, 31, and 44.) These experiments were made however for the purpose of determining conductive capacity, without any view of employing the indications for signals.

A letter was published in the *Scots' Magazine*, dated Renfrew, February 1, 1753, and signed "C. M.," which, under the title "An expeditious method of conveying intelligence," proposed the suspension between two distant points of a number of insulated wires (equal to the number of letters in the alphabet), through which electrical discharges should separately exhibit themselves by the diverging balls of an electroscope, or the striking of a bell by the attraction of a charged ball. The author of the communication was supposed by Sir David Brewster to be a Charles Marshall, of Paisley. (*The Engineer*, London, Dec. 24, 1858, vol. vi., p. 484.) It is probable that G. L. Lesage, of Geneva, entertained the project of an electric telegraph as early as the middle of the last century. It was therefore rather the impulse of an age, than the inspiration of an individual.

‡ The application of magneto-electricity, presenting no essential differences from the use of galvano-electricity, (for which it is sometimes substituted,) requires no special notice. Still less noteworthy is the project of thermo-electricity as the motor.

§ *Prolusiones Academicæ:* by F. Strada, quarto, Rome, 1617, lib. ii, prolusio 6. A century later, (but still a third of a century before man dreamed of electric telegraphs,) Joseph Addison presented the following version of this fairy tale: "Strada, in one of his Prolusions, gives an account of a chimerical correspondence between two friends by the help of a certain loadstone which had such a virtue in it that if it

"Two faithful needles—from the informing touch
Of the same parent stone, together drew
Its mystic virtue;——
And though disjoined by kingdoms,—though the main
Rolled its broad surge betwixt,—and different stars
Beheld their wakeful motions,—yet preserved
Their former friendship and remembered still
The alliance of their birth." *

It needed but the later discovery of the galvanic wire for connecting the two needles, to realize completely this vision of an "oriental" fancy, and to render it the sober experience of our present every-day life.

I.—TELEGRAPHS BY ELECTRICITY.

If the earlier attempts commencing in the last century to apply so-called "static" electricity to the purpose of telegraphy may to some appear to possess only an antiquarian interest, it will be seen that they form the necessary, and by no means insignificant, childhood of our modern systems. Neglecting generally mere speculations, as well as initial conceptions of executed schemes, the following comprise the more important experimental devices, in the order of their approximate realization.

1774. The first electric telegraph of which there is record, is that established at Geneva by Georges-Louis Lesage. The line consisted of 24 insulated wires for the alphabet, each terminating in a pith-ball electroscope duly lettered, for indicating by its excitement the succession forming the words and sentences given by the operator, who employed at the transmitting station a manual conductor from an electrical machine. †

1787. M. Lomond, at Paris, had a single brass wire extended from one closed apartment to another at some distance from it, in connection with a pith-ball electroscope at each end, by which arrangement he was able to communicate sentences in either direction. Arthur Young, the diligent writer on natural and industrial resources, has thus described the apparatus in his journal: October 16, 1787,—" In the evening, to Mons.

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touched two several needles, when one of the needles so touched began to move, the other though at never so great a distance, moved at the same time and in the same manner. He tells us that the two friends being each of them possessed of one of these needles, made a kind of dial-plate, inscribing it with the four-and-twenty letters, in the same manner as the hours of the day are marked upon the ordinary dial-plate. They then fixed one of the needles on each of these plates in such a manner that it could move round without impediment, so as to touch any of the four-and-twenty letters. . . . By this means they talked together across a whole continent, and conveyed their thoughts to one another in an instant over cities or mountains, seas or deserts." (*The Spectator*, No. 241, Dec. 6, 1711.) A similar idea (probably borrowed from Strada) is found in Daniel Schwenter's *Mathematisch-philosophische Erquickungsstunden;* published at Nuremberg in 1636, pp. 346, 347.

*Akenside, *Pleasures of Imagination* (1744), book iii.

† Lesage, in a letter addressed to Prof. Pierre Prévost, of Geneva, dated Berlin, June 22, 1782, describing to his friend the details of his telegraph, states that the method of corresponding by means of electricity had been contemplated by him for thirty or thirty-five years. (*Traité de Télégraphie Électrique:* par l'Abbé Moigno, 2d edit. 8vo. Paris, 1852, part ii, chap. 1, p. 59.)

Lomond, a very ingenious and inventive mechanic, who has made an improvement of the jenny for spinning cotton. In electricity he has made a remarkable discovery. You write two or three words on a paper; he takes it with him into a room, and turns a machine inclosed in a cylindrical case, at the top of which is an electrometer,—a small fine pith ball; a wire connects with a similar cylinder and electrometer in a distant apartment; and his wife by remarking the corresponding motions of the ball, writes down the words they indicate. From which it appears that he has formed an alphabet of motions. As the length of the wire makes no difference in the effect, a correspondence might be carried on at any distance." *

1794. M. Reiser, at Geneva, arranged a line of 36 insulated wires, each separately connected at the receiving-station with a small grating of narrow tin-foil strips pasted on glass, from which a letter or figure had been cut, so as to represent the character by the passage of the electric spark over the series of narrow spaces. On a square plate were fastened 36 of these independent gratings, representing the 26 letters and 10 numerals. "The instant the discharge is made through the wire, the spark is seen simultaneously at each of the interruptions or breaks of the tin-foil constituting the letter, and the whole letter is rendered visible at once." The sparks were transmitted through the selected wire and its corresponding symbol from a small electrical machine kept in operation at the sending station. †

1795. Tiberius Cavallo, in England, experimented with electric signals of various kinds (explosive and otherwise) through a long and tolerably fine copper wire (about the fortieth of an inch in diameter) insulated by successive coatings of pitch, linen strips, woolen cloth, and oil-painting. He found a Leyden jar of about one square foot, sufficient for the required electric spark, if the length of the wire did not exceed 200 feet. He remarks: "By sending a number of sparks at different intervals of time according to a settled plan, any sort of intelligence might be conveyed instantaneously from the place in which the phial is situated. With respect to the greatest distance to which such communication might be extended, I can only say that I never tried the experiment with a wire of communication longer than about 250 feet; but from the results of those experiments, and from the analogy of other facts, I am led to believe that the above-mentioned sort of communication might be extended to two or three miles, and probably to a much greater distance." ‡

* *Travels during the years* 1787, 1788, *and* 1789, *in the Kingdom of France*. By Arthur Young. 2 vols. 8vo. Dublin, 1793, vol. i, p. 135. Of the work as republished in Pinkerton's *Collection of Voyages and Travels*, 4to. London, 1809, vol. iv, p. 139.

† Voigt's *Magazin*, etc. 1794, vol. ix, part 1, p. 183; also Moigno's *Télégraphie Électrique*, part ii, chap. 1, p. 61.

‡ *A Complete Treatise on Electricity*, in 3 vols. 8vo. London, 1795; vol. iii, note No. viii, pp. 295, 296. The first *two* volumes of this work had passed through three earlier editions.

1798. D. F. Salva, in Spain, appears to have successfully worked an electric telegraph through the unprecedented distance of twenty-six miles. "The *Madrid Gazette* of November 25, 1796, states that the Prince de la Paix, having heard that M. D. F. Salva had read to the Academy of Sciences a memoir upon the application of electricity to telegraphing, and presented at the same time an electric telegraph of his own invention, desired to examine it; when being delighted with the promptness and facility with which it worked, he presented it before the king and court, operating it himself. Some useful trials were made and published in *Voigt's Magazine.* Two years after, the Infanta Don Antonio constructed a telegraph of great extent on a large scale, by which the young prince was informed at night of news in which he was much interested. He also invited and entertained Salva at court. According to Humboldt, a telegraph of this description was established in 1798, from Madrid to Aranjuez, a distance of 26 miles."*

1816. Francis Ronalds constructed at Hammersmith, England, an experimental telegraph line of a single wire, operated by an electrical machine, or small Leyden jar. "He proved the practicability of such a scheme by insulating eight miles of wire on his lawn at Hammersmith. In this case the wire was insulated in the air by silk strings. . . . Mr. Ronalds fixed a circular brass plate upon the seconds arbor of a clock which beat dead seconds. This plate was divided into twenty equal parts, each division being worked by a figure, a letter, and a preparatory sign. The figures were divided into two series of the units, and the letters were arranged alphabetically, omitting J, Q, V, W, X, and Z. In front of this was fixed another brass plate (which could be occasionally turned round by hand), and which had an aperture that would just exhibit one of the figures, letters, and preparatory signs. In front of this plate was suspended a pith-ball electrometer from a wire which was insulated and which communicated on one side with a glass cylinder machine. At the farther end of the wire was an apparatus exactly the same as the one now described, and the clocks were adjusted to as perfect synchronism as possible. Hence it is manifest that when the wire was charged by the machine at either end, the electrometers at both ends diverged, and when it was discharged they collapsed at the same instant; consequently if it was discharged at the moment when a given letter, figure, and sign on the plate appeared through the aperture, the same letter, figure, and sign would appear also at the

* *The Electro-Magnetic Telegraph*, by Laurence Turnbull, 8vo. 2d ed. Philada. 1853, pp. 21, 22. Voigt's *Magazin*, etc. vol. xi, part 4. The same telegraphic feat is attributed to Bétancourt. "Gauss makes mention of a communication from Humboldt, according to which Bétancourt, in 1798, established a communication between Madrid and Aranjuez, a distance of 26 miles, by means of a wire through which a Leyden jar used to be discharged, which was intended to be used as a telegraphic signal." (Sturgeon's *Annals of Electricity*, etc. March, 1839, vol. iii, p. 446.) This is probably a misapprehension; as Augustine Bétancourt (more correctly Bethencourt), a Spanish engineer, in 1798, devised and exhibited to the National Institute an improvement in the mechanical semaphore. (Brewster's *Edinburgh Encyclopædia*, 1830, art. "Telegraph,' vol. xviii, p. 535.)

other clock; so that by means of such discharges at one station, and by marking down the letters, figures, and signs seen at the other, any required words could be spelt."*

"He also made the trial with 525 feet of buried wire. With this view he dug a trench four feet deep, in which he laid a trough of wood two inches square, well lined both within and without with pitch; and within this trough were placed thick glass tubes through which the wire ran. The junction of the glass tubes was surrounded with short and wider tubes of glass, the ends of which were sealed up with soft wax." This form of conductor was not found to operate very satisfactorily, and the inventor on theoretical grounds did not think such an arrangement adapted to the instantaneous electrical transmission required by his system.

Mr. Ronalds, in 1823, published a full account of his telegraph.† In 1871, very nearly half a century later, as Sir Francis Ronalds, he published a new edition of this interesting work; and a review of it in "Nature" gives this presentation of the scheme: "Sir Francis, before 1823, sent intelligible messages through more than eight miles of wire insulated and suspended in the air. His elementary signal was the divergence of the pith-balls of a Canton's electrometer, produced by the communication of a statical charge to the wire. He used synchronous rotation of lettered dials at each end of the line, and charged the wire at the sending end whenever the letter to be indicated passed an opening provided in a cover; the electrometer at the far end then diverged, and thus informed the receiver of the message which letter was designated by the sender. The dials never stopped, and any slight want of synchronism was corrected by moving the cover."‡

This very ingenious device of synchronous rotation at the opposite stations presents the earliest example of a dial telegraph, or of a letter indicator employing but a single wire. About forty years later, or in 1855, this system was successfully applied by Mr. David E. Hughes, of Kentucky, to a letter-printing telegraph of remarkable rapidity and accuracy.§

1828. "Harrison Gray Dyar, an American, constructed a telegraph in 1827-'28, at the race-course on Long Island, and supported his wires by glass insulators fixed on trees and poles. By means of common electricity acting upon litmus paper he produced a red mark. The difference of time between the sparks indicated different letters arranged in an ar-

*_Encyclopædia Britannica_, 7th ed. 1842, vol. viii, p. 662.—8th ed. 1854, vol. viii, p. 627.

†_Descriptions of an Electrical Telegraph; and some other Electrical Apparatus._ By Francis Ronalds. 8vo. London, 1823.

‡_Nature._ London, Nov. 23, 1871, vol. v, p. 59.

§A second type of dial telegraph was invented by Prof. Charles Wheatstone in 1839, in which the dial (or index) was rotated step by step by means of successive impulses of the current on an electro-magnet, which operated a toothed escapement on the axis of the dial or index;—the indicated letter or figure being stopped as long as desired. In this case, the character was determined solely by the number of electric impulses transmitted. This system was in 1846, made the basis of a highly original letter-printing telegraph, by Mr. Royal E. House, of Vermont; preceding that of Mr. Hughes, as will be observed, nearly ten years.

bitrary alphabet, and the paper was moved by the hand."* Mr. Dyar is described by Dr. Luther V. Bell as "a man of the highest inventive skill and scientific attainments." His experimental line (of a single wire) was several miles long; and the chemical record of the signals transmitted through it, was by the testimony of those who witnessed its operations, eminently distinct and satisfactory. The following is the account of his enterprise, given by the inventor himself in 1849, some twenty years afterward:

"I invented a plan of a telegraph which should be independent of day or night or weather, which should extend from town to town or city to city, without any intermediary agency, by means of an insulated wire in the air, suspended on poles, and through which wire I intended to send strokes of electricity in such a manner as that the diverse distances of time separating the divers sparks should represent the different letters of the alphabet and stops between the words, etc. This absolute or this relative difference of time between the several sparks I intended to take off from an electric machine by a little mechanical contrivance regulated by a pendulum, and the sparks were intended to be recorded upon a moving or a revolving sheet of moistened litmus paper, which by the formation of nitric acid by the spark in the air in its passsage through the paper, would leave a red spot for each spark on this blue test-paper. . . . To carry out my invention I associated myself with a Mr. Brown, of Providence, who gave me certain sums of money to become associated with me in the invention. We employed a Mr Connel, of New York, to aid in getting the capital wanted to carry the wires to Philadelphia. This we considered as accomplished: but before beginning upon the long wire, it was decided that we should try some miles of it on Long Island. Accordingly I obtained some fine card wire, intending to run it several times around the race-course on the Island. We put up this wire (that is, Mr. Brown and myself) at different lengths, in curves and straight lines, by suspending it from stake to stake and tree to tree until we concluded that our experiments justified our undertaking to carry it from New York to Philadelphia. At this moment our agent brought a suit or summons against me for 20,000 dollars for agencies and services, which I found was done to extort a concession of a share of the whole project." Failing in this prosecution, the unprincipled agent obtained a writ against the two partners on a charge of conspiracy to carry on secret communication between the cities! and he thus effectually put an end to the enterprise, without the formality of a judicial trial on this novel accusation.†

These practical illustrations of early electric telegraphy, including successful workings of both the dial and the chemical forms of the telegraph without the use of galvanism, serve to show that the agency is by

*Turnbull's *Electro-Magnetic Telegraph*, 8vo. Philadelphia, 1st ed. 1852, p. 6; 2d ed. 1853, p. 22.

† Prescott's *Hist. Electr. Telegraph*, 1860, chap. xxi, pp. 427, 428.

no means the trivial and inefficient one so often represented by modern writers. On the contrary, but for the practical difficulty of perfect and constant insulation, owing to the intense self-repulsion of mechanical electricity and the reaction and retardation from induction currents in long lines of coated wire, this method would really constitute an economical and satisfactory medium of distant communication.

Steinheil in reference to this subject remarks: "All these experiments put it beyond a doubt that frictional electricity may be employed for giving signals at any distances, and that when these signals are properly contrived they offer convenient means of telegraphic intercourse. Frictional electricity has besides as Gauss has already observed, the great advantage of not losing any of its force by increasing the length of the conducting wire, inasmuch as the whole of the electricity of one coating of the jar must traverse the entire length of the wire (be it what it may) to neutralize that of the other coating." *

II.—TELEGRAPHS BY GALVANISM.

The introduction of the galvanic battery by Volta at the commencement of the present century † led many to experiment with its peculiar current as a means of telegraphing. The only practicable forms of simple galvanic telegraphs, are those whose indications are given by chemical decompositions, and which thus form the class commonly known as the "electro-chemical"; and as these chemical indications usually leave permanent markings, the class is also one of *recording* telegraphs.

1808. Dr. Samuel Thomas von Sœmmering, of Munich, appears to have been the first to apply Volta's invention to this purpose. "As long ago as in 1807, Sœmmering erected in the apartments of the Academy of Sciences at Munich a galvanic telegraph, of which he has published a detailed description in the Philosophical Transactions of Bavaria. [*Münchner Denkschriften der Königlichen Akademie der Wissenschaften für* 1809, 1810. Math. phys. Classe, p. 401.] He employed the energy of a powerful voltaic pile to bring about the decomposition of water by means of thirty-five gold pins immersed in an oblong glass trough." ‡ Each of these gilt electrodes was in connection with one of the thirty-five wires forming the line, and was covered with an inverted test-tube filled with water, resting on a submerged shelf in the oblong trough, as a gas-receiver. These small receivers with their inclosed gilt pins or electrodes arranged in a row, represented 25 letters and 10 numerals. Such being the disposition at the receiving end, the thirty-five line wires at the transmitting end were each secured to a separate perforated brass plate. On connecting the

* Sturgeon's *Annals of Electricity*, etc. March 1839, vol. iii, p. 446.

† Volta's description of his battery is given in a "Letter to Sir Joseph Banks," president of the Royal Society of London. (*Phil. Trans. R. S.* read June 26, 1800, vol. xc, pp. 403–431.)

‡ Sturgeon's *Annals of Electricity*, etc. Mar. 1839, vol. iii, p. 447.

respective poles of the battery with any two of the line wires by means of two attached metallic pins held in the hands and inserted in the holes of their terminal plates, the current was established, and bubbles of hydrogen and oxygen were at once evolved in the corresponding lettered tubes. A system of syllabic communication and reading was provided, in which the hydrogen element should be first noted.*

Very shortly after his first successful working of this telegraph, Sœmmering interposed in the galvanic circuit two thousand feet of insulated wire, wound around a glass cylinder, without impairing his decompositions. He found no appreciable retardation in the action of the electrodes. "The evolution of the gas through this considerable length of wire appeared to begin as quickly as if the effect had only to traverse two feet." †

In an "Historical account of the introduction of the galvanic and electro-magnetic telegraph" presented to the Imperial Academy of Sciences at St. Petersburg, by Dr. Hamel, of that city, a very full and interesting narrative is given of Sœmmering's experiments, compiled from original documents; ‡ from which the following extracts are made:

"On the 22d of July, 1809, his apparatus was already so far advanced that it was fit to work. He however went on making still further improvements, and it was only on the 6th of August that he considered the telegraph quite completed. He was much pleased with its performance, being able to work through 724 feet of wire. . . . Two days later, he could already telegraph through 1,000 feet, and on the 18th of August through as much as 2,000 feet of wire. On the 29th of August he exhibited the telegraph in action before a meeting of the Academy of Sciences, in Munich." A year later he first effected a satisfactory arrangement of premonitory alarm or attention call. "On the 23d of August, 1810, Sœmmering succeeded in inventing a contrivance for sounding an alarm, which answered perfectly well." (p. 596.)

"In September, 1811, Sœmmering simplified his telegraph considerably; he reduced the number of wires in his conducting cord from 35 to 27. . . . On the 1st of February, 1812, Prince Karl Theodor, the second son of King Maximilian I, honored Sœmmering with a visit to see the telegraph. On the 4th of February, 1812, Sœmmering announced that he was able to telegraph through 4,000 feet of wire, and on the 15th of March he telegraphed even through 10,000 feet." (p. 597.) This was nearly two miles of wire, but wound on reels.

This complex and inconvenient arrangement of signaling by the decomposition of water, would hardly seem to offer a practical method of telegraphy. Yet the system was earnestly prosecuted by its inventor for

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* Schweigger's *Journal für Chemie und Physik*, 1811, vol. ii, part 2, pp. 217–213: (from the *Memoirs* of the "*Königliche Akademie der Wissenschaften*," at Munich, 1810.) Also, *Polytechnisches Central-Blatt*, June, 1838, Jahrgang iv, b. i, pp. 482–484.

† *Münchner Denkschriften der Königlichen Akademie der Wissenschaften* für 1812. In this experiment, the self-induction of the conducting coil probably increased somewhat the effect.

‡ *Journal of the Society of Arts*, London, July 22, and 29, 1859, vol. vii, No. 348, pp. 595–599, and No. 349, pp. 605–610.

many years, and attracted considerable attention; and had no simpler device been discovered it might possibly have won its way into use. It is remarkable that some seven or eight years later a Philadelphian independently proposed the same scheme.

1816. Dr. John Redman Coxe, of Philadelphia, professor of chemistry in the University of Pennsylvania, suggested the employment of wires for communicating intelligence by a galvanic current, arranged either to decompose water in tubes, (Sœmmering's plan, of which he seems to have been unaware,) or to decompose metallic salts.* As an untried suggestion, this has been noticed only because the latter project was afterward successfully developed and executed by others.

1828. Victor Triboaillet de Saint Amand proposed to establish a galvanic telegraph line of a single wire from Paris to Brussels, the conducting wire to be varnished with shellac, wound with silk, coated with resin, inclosed in sections of glass tube carefully luted with a resin, the whole substantially wrapped and water-proofed, and finally to be buried some feet deep in the earth. The signaling device is somewhat obscure, as while a strong battery is the source of the current, the receiving instrument is an electrometer.† This project, also belonging to the purely speculative class, scarcely deserves a notice.

1843. Mr. Robert Smith, of Blackford, Scotland, devised an experimental galvano-chemical telegraph carrying out practically the suggestion offered by Dr. Coxe in 1816. A set of iron type at the receiving station, each connected by separate wires with a corresponding circuit-key at the transmitting station, was so arranged with reference to a clock-moved band of paper wet with a solution of ferro-cyanide of potassium, that when the current was passed through any special circuit, it impressed a blue letter on the band. "A paper containing an account of this telegraph was read before the Royal Scottish Society of Arts on the 27th of March, 1843; reported on by a committee, and approved the 12th of June following. Since that time many trials have been made, and various improvements in its construction have also been introduced by the inventor." ‡

Two or three years later Mr. Smith reduced his line to a single circuit of two wires; and the registering device at the receiving station consisted of a fillet or ribbon of plain calico wound on a roller placed in a trough filled with a solution of ferro-cyanide of potassium containing a few drops of nitric acid, and unrolled by the motion of clock-work over a leaden cylinder with which one of the iron wires of the line was in connection, while the end of the other iron wire rested on the wetted

*Thomson's *Annals of Philosophy*, Feb. 1816, vol. vii, p. 162.

† *Report of Academy of Industry*, Paris. Quoted from A. Vail's *Electro-Magnetic Telegraph*, 1845, p. 135. Also Turnbull's *Electro-Magnetic Telegraph*, 2d ed. 1853, p. 56.

‡ *Practical Mechanic and Engineer's Magazine*, Glasgow, Nov. 1845, vol. i, 2d series, p. 36.

calico immediately over the cylinder. On every completion of the circuit at the transmitting station, a blue mark was thus imprinted on the moving cloth by the electrical decomposition, and the succession of marks of differing lengths and intervals formed the system of signals. This telegraph was found to work satisfactorily through eighteen hundred yards of wire fence.*

1846. Mr. Alexander Bain, of Edinburgh, obtained an English patent for a galvano-chemical telegraph, which while exhibiting considerable ingenuity in its mechanical devices, imitated very closely in its chemical record the previous system of Smith. "The chemical solution preferred for the preparation of the paper consists of sulphuric acid and a solution of prussiate of potassa."†

1849. Prof. Samuel F. B. Morse, of New York, obtained an American patent for a galvano-chemical telegraph, also very similar to that of Smith, employing like him a single circuit, and specifying, among several metallic salts which might be used, solutions of iodide of potassium, of iodide of tin, and of acetate of lead, with nitrate of potassa. The inventor added: "I wish it to be understood that I do not confine myself to the use of the substances I have mentioned, but mean to comprehend the use of any known substance already proved to be easily decomposed by the electric current."‡

III.—TELEGRAPHS BY GALVANO-MAGNETISM.

Meanwhile the rapid awakening of attention among physicists to the magnetic relation of the galvanic current, and the production of the galvanometer, at once indicated a new and promising method of signaling to a distance by galvanic agency.

The Galvanometer.—In 1820, Hans Christian Oersted, professor of natural philosophy at Copenhagen, announced through various European journals his discovery that if a straight conjunctive wire through which a galvanic current is passing "be placed horizontally above the magnetic needle and parallel to it . . . the needle will be moved, and the end next the negative side of the battery will go westward. . . . If the uniting wire be placed in a horizontal plane *under* the magnetic needle all the effects are the same as when it is above the needle, only they are in an opposite direction."§

Although the directive influence of a galvanic conductor on a mag-

* *Practical Mechanic and Engineers' Magazine*, June, 1846, vol. i, 2d series, pp. 239, 240.

† *English patent* of A. Bain, Dec. 12, 1846, No. 11480.

‡ *American patent* of S. F. B. Morse, May 1, 1849, No. 6420.

§ Thomson's *Annals of Philosophy*, Oct. 1820, vol. xvi, pp. 274, 275. (Also, *Journal de Physique*, etc. 1820, vol. xci, pp. 72–76; *Annales de Chimie et de Physique*, 1820, vol. xiv, pp. 417–425; *Bibliothèque Universelle des Sciences*, etc. 1820, vol. xiv, pp. 274–284; *Annales Générales des Sciences Physiques*, 1820, vol. v, pp. 259–264; Gilbert's *Annalen der Physik*, 1820, vol. lxvi, pp. 295–304; Schweigger's *Journal für Chemie und Physik*, 1820, vol. xxix, pp. 275–281; *Giornale Arcadico di Scienze*, etc. 1820, vol. viii, pp. 174–178; Brugnatelli's *Giornale di Fisica*, etc. 1820, pp. 335–342.)

netic needle, was observed and announced by an Italian savant, Gian Domenico Romagnosi, of Trent, at the beginning of the present century, (shortly after the production of the galvanic battery by Volta,) this important phenomenon attracted no attention, and produced no results, until it was republished two decades later by the Danish physicist.*

In the same year—almost immediately after Oersted's announcement, Prof. Johann S. C. Schweigger, of Halle, made a great improvement on his galvano-magnetic indicator (of a single wire circuit), by giving the insulated wire a number of turns around an elongated frame longitudinally inclosing the compass-needle, and by thus multiplying the effect of the galvanic circuits upon the sensibility of the needle converted it into a real *measuring* instrument,—a "galvanometer."†

This delicate indicator at once suggested a new mode of galvanic telegraphing. In a memoir read to the "Royal Academy of Sciences," at Paris, October 2, 1820, André Marie Ampère, affirming "the possibility of deflecting a magnetic needle at a great distance from the pile, through a very long conducting wire," remarked: "This experiment, suggested to me by the illustrious Laplace, was completely successful. . . . From the success of the experiment" he added, "it is feasible by means of as many conducting wires and magnetic needles as there are letters, (each letter being assigned to a separate needle,) and by help of a battery at a distance, with its poles alternately connected with the extremities of each conductor, to establish a kind of telegraph adapted to transmit over intervening obstacles whatever information may be desired to the person observing the letters of the needles. A set of keys near the battery, bearing corresponding letters and making connection by their depression, would offer a facile means of correspondence; re-

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*As early as 1802, eighteen years before Oersted's discovery, M. Romagnosi, a publicist and physicist of Trent, observed the deflection of the magnetic needle when placed near a parallel conductor of the galvanic current. An account of this discovery was published in the *Gazzétta di Trento*, August 3, 1802. See "Supplement," NOTE B.

† "Additions to Oersted's Electro-magnetic Experiments," a memoir read at the *Naturforschenden Gesellschaft* at Halle, September 16 and November 4, 1820. An abstract of this paper was published in the *Allgemeine Literatur-Zeitung* of Halle, (4to,) November, 1820, No. 296, vol. iii, col. 621–624. The full memoir appeared in the *Journal für Chemie und Physik*, 1821, vol. xxxi, pp. 1–17; and "Additional Remarks," etc. by Dr. Schweigger, in the same volume, pp. 35–41.

A galvanometer of somewhat different form, having a vertical helix and employing an unmagnetized needle, was very shortly afterward independently devised by Johann Christian Poggendorff, of Berlin; and as he preceded Schweigger in publishing an account of it, he is sometimes regarded as the original inventor. (*Edinburgh Philosophical Journal*, July, 1821, vol. v, p. 113.) Schweigger designated his device an "Electro-magnetic Multiplicator"; Poggendorff designated his arrangement a "Galvano-magnetic Condensator." Professor Oersted remarks, "Immediately after the discovery of electro-magnetism, M. Schweigger, professor at Halle, invented an apparatus admirably adapted for exhibiting by means of the magnetic needle, the feeblest electric currents. . . . M. Poggendorff, a distinguished young savant of Berlin, constructed an electro-magnetic multiplier very shortly after M. Schweigger, with which he made some striking experiments. M. Poggendorff's work having been cited in a book on electro-magnetism by the celebrated M. Ernan, (published immediately after the discovery of these phenomena,) became known to several philosophers before that of M. Schweigger." (*Annales de Chimie et de Physique*, 1823, vol. xxii, pp. 358–360.)

quiring only the time to touch each key at the one station, and to read each letter at the other."*

Ingenious as this early proposal of an electro-magnetic telegraph appears, it really presents essentially but the substitution of the new-found galvanometer for the old electrometer at the receiving station, as first employed by Lesage, nearly half a century previously.

1823. The first to develop practically, Ampère's suggestion of a galvanometer telegraph, was the Russian Baron Paul Ludovitsch Schilling, of Cronstadt. The personal friend of Sœmmering, he became from an early date warmly interested in the galvanic telegraph; and not long after Schweigger's invention of the galvanometer, he appears to have commenced his experiments in the direction pointed out by Ampère. His countryman, the venerable Dr. Hamel, of St. Petersburg, who enjoyed his acquaintance, gave in 1859, in his "Historical account of the introduction of the galvanic and electro-magnetic Telegraph," the following interesting particulars of Schilling's early associations and pursuits:†

"At the time when Sœmmering became a member of the Academy of Sciences at Munich, in 1805, there was attached to the Russian embassy in that capital, the Baron Pavel Ludovitsch Schilling, of Cronstadt. About a year after the invention of the telegraph [by the former] Schilling saw experiments performed with it. He was so forcibly struck with the probability of a very great usefulness of the invention that from that day galvanism and its applications became one of his favorite studies."

"In the spring of 1812, Baron Schilling was endeavoring to contrive a conducting cord sufficiently insulated that it might convey the galvanic current not only through wet earth, but also through long distances of water. The war then impending between France and Russia made Baron Schilling desirous of finding a means by which such a conducting cord should serve for telegraphic correspondence between fortified places and the field, and likewise for exploding powder mines across rivers. . . . In the autumn of 1812, he actually exploded powder mines across the river Neva, near St. Petersburg. . . . Baron Schilling has told me that during his stay at Paris, he with his subaqueous conductor, several times (to the astonishment of the lookers-on) ignited gunpowder across the river Seine."

"On the 29th of December, 1815, there came to pay his respects to Sœmmering (while Baron Schilling was just with him) the well-known natural philosopher Johann Salomon Chistian Schweigger, then professor of natural philosophy and chemistry at the Physico-technical Institute at Nuremberg, who was on his way to Paris and London: (in which

* *Annales de Chimie et de Physique*, 1820, vol. xv, pp. 72, 73.

† The writer states: "Letters show that the cordial friendship between Sœmmering and Baron Schilling continued unchanged to the time of his decease in 1830." Schilling died August 7, 1837. Dr. Hamel himself had the fortune to be personally acquainted with Oersted, Schweigger, Ampère, Arago, Sœmmering, Schilling, and other electro-magnetic and telegraphic celebrities.

latter place I had afterward the pleasure of making his acquaintance.) . . . Baron Schilling having made at Sœmmering's the acquaintance of Schweigger, of course could not foresee that one day an invention of this gentleman, the 'multiplier,' would enable him to make at St. Petersburg, the first electro-magnetic telegraph."*

It is impossible, in the scarcity of documentary evidence, to ascertain at what date Schilling's long contemplated project of a galvanometer telegraph (designed as an improvement on the galvanic telegraph of his friend Sœmmering) was first reduced to a practical or working form: but it was at least as early as the year 1823, when Schilling constructed at St. Petersburg an electro-magnetic telegraph apparatus whose signals were produced by five galvanometer needles, each provided with its own independent galvanic circuit. Schilling was enabled to effect his great simplification of an original alphabet of circuits, by the ingenious expedient of giving to each needle a positive and negative motion by means of reversed currents, and then of combining two or more of these signals. Whether this was really Schilling's first form of apparatus is very doubtful; but it is at least certain that he exhibited an operative instrument before the Emperor Alexander in 1824, or in 1825.†

Dr. Hamel remarks: "It was reserved for Baron Schilling at St. Petersburg to make the first electro-magnetic telegraph. Having become (as we know) through Sœmmering, at Munich, passionately fond of the art of telegraphing by means of galvanism, he now used for it the deflection of the needle, which he placed within the 'multiplier' of Schweigger horizontally on a light vertical axle hanging on a silken thread, and bearing a circular disk of paper colored differently on each side. . . . By degrees he simplified the apparatus. For a time he used five needles, and at last he was able to signalize even with one single needle and multiplier, producing by a combination of movements in the two directions, all the signs for letters and numbers. Having known Sœmmering's alarum, Schilling invented one for his telegraph also. His success in bringing his instruments to a high state of perfection would have been much more rapid had his time not been so much occupied with various duties, and particularly with the founding and directing of a large lithographic establishment for the Russian Government. Baron Schilling's telegraph was an object of great curiosity at St. Petersburg; it was frequently exhibited by him to individuals and to parties. Already the Emperor Alexander I, had been pleased to notice it in its earlier stage, and when it was reduced to great simplicity, his Majesty the Emperor Nicholas honored Baron Schilling on the 13th of March, 1830, with a visit at his lodgings in Opotchinin's house, in the Konooshennaja, to see experiments performed with it through a great length of conducting wires. . . .

"In May of the last-mentioned year (1830) Baron Schilling undertook a journey to China. . . . After his return from the borders of China to

Journal of the Society of Arts, July 22, 1859, vol. vii, pp. 597, 598.

†The Emperor Alexander died in 1825.

St. Petersburg, in March, 1832, Baron Schilling occupied himself again with the telegraph, and in May, 1835, he undertook a journey to the west of Europe, taking his simplified instrument with him. In the month of September he attended the meeting of the German physicists at Bonn on the Rhine, where on the 23d he exhibited his telegraph before the section of natural philosophy and chemistry, over which Professor Georg Wilhelm Muncke, of the University of Heildelberg, presided. Muncke was much pleased with Schilling's instrument, and he determined at once to get one for exhibition at his lectures. I have lately found at Heidelberg . . . in a store-room, the apparatus which Professor Muncke got made in imitation of the one exhibited by Baron Schilling at Bonn." *

The conflicting accounts of Schilling's system given at a later date appear to refer to instruments constructed at different periods. Thus it is said that in the latter part of 1832 [!] he used a "certain number of platinum wires insulated and united in a cord of silk, which put in action, by the aid of a species of key, 36 magnetic needles, each of which was placed vertically in the center of a multiplier. M. de Schilling was the first who adapted to this kind of apparatus an ingenious mechanism suitable for sounding an alarm, which when the needle was turned at the beginning of the correspondence, was set in play by the fall of a little ball of lead which the magnetic needle caused to fall. This telegraph of M. de Schilling was received with approbation by the Emperor, who desired it established on a larger scale: but the death of the inventor postponed the enterprise indefinitely." †

It is also stated in another account, that Schilling exhibited his telegraphic instruments before the Emperor Alexander. "In order to apprise the attendant before the commencement of a telegraphic dispatch, Schilling set off an alarm. How much of his apparatus belongs properly to the Baron Schilling, or whether a part of it was not an imitation of that of Gauss and Weber, is not for the editor to decide; but that Schilling had already experimented (probably with a more imperfect apparatus) before the Emperor Alexander, and subsequently before the Emperor Nicholas, is affirmed by the authorities adduced." The account describes the communications as consisting of signs devised from the various combinations of the right and left deflections of the single nee-

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* *Journal of the Society of Arts*, July 29, 1859, vol. vii, pp. 606, 607. The apparatus above referred to, is noteworthy as being that seen by Mr. William Fothergill Cooke on attending one of the lectures by Professor Muncke, at Heidelberg, March 6, 1836, on the electro-magnetic telegraph; and which apparatus he proceeded immediately to have reproduced. Returning to London April 22, of the same year, Mr. Cooke, (in conjunction with Professor Wheatstone,) succeeded by his energy in introducing the needle telegraph into England: and thus Schilling's great invention became transplanted from St. Petersburg to London, without either of its English introducers having any idea of its true origin. As Dr. Hamel remarks: "Mr. Cooke, who had never occupied himself with the study either of natural philosophy in general, or of electricity in particular, did not at all get further acquainted with Professor Muncke. He did not even acquire his name properly; he calls him Möncke. He had no idea that the apparatus he had seen had been contrived by Baron Schilling in Russia."

† *Report* of the "Academy of Industry," Paris, February, 1839.

dle.* It must evidently have been at a later date than 1825 when Schilling reduced his telegraph line to a single circuit of two wires and employed but a single galvanometer. Whether Schilling or Gauss was the original inventor of that most important improvement in galvanic telegraphy, the simplification and reduction of the line of communication to a single circuit cannot now perhaps be definitely determined; † but that the credit belongs to Schilling seems highly probable. That Schilling first invented and constructed a practical and operative electro-magnetic telegraph apparatus is placed beyond dispute; although the historical evidences of actual date are somewhat obscure. It is remarkable that although Schilling's early experimental telegraph was widely exhibited, and to numbers of distinguished visitors, no contemporary publication of its character or construction was made; and the invention was unknown to Western Europe for a dozen years later.‡

Thus, in 1829, Gustav Theodor Fechner, of Leipsic, evidently quite unaware of Schilling's labors—years before, wrote in a text-book on Galvanism: "There is no doubt that if the insulated wires of twenty-four multipliers, representing the letters of the alphabet (situated in Leipsic, for example), were conducted underground to Dresden, where should be placed a battery, we would have thereby a medium of communication probably not very expensive, through which intelligence could be instantaneously transmitted from one city to another."§

And in the year following, 1830, Dr. William Ritchie, at London, in a lecture before the Royal Institution on the evening of February 12, exhibited a working model of a telegraph provided with 26 circuits of wire for the several letters of the alphabet, "Mr. Ritchie concluded by exhibiting the electro-magnetic telegraph proposed by Ampère, by means of which, rapid communication might be carried on between towns in every state of the weather. The lecturer concluded by observing that in the present state of the inquiry, we cannot pronounce with absolute certainty with regard to the success of this ingenious project." ||

The Electro-Magnet.—But almost simultaneously with the birth of the galvanometer, this fertile agent—electricity—developed a new and no less

* *Polytechnisches Central-Blatt*, June, 1838, Jahrgang iv. b. i, p. 486.

† One of the foremost of telegraphic inventors, and the personal friend of Gauss, Steinheil himself, speaks thus uncertainly on this subject: "The experiments instituted by Schilling by the deflection of a single magnetic needle, seem much better contrived [than Ampère's plan of an alphabet of wires, adopted by Mr. Davy and others]; he did not, however, succeed in surmounting the mechanical difficulties that attend the question in this shape . . . Gauss, and probably in imitation of him, Schilling . . . made use of but a single wire running to the distant station and back." (Sturgeon's *Annals of Electricity*, etc. March, 1839, vol. iii, pp. 448 and 450.)

‡ In 1835, Schilling, assisted by Baron Jacquin and Professor Ettingshausen, experimented with telegraph wires extended over the houses and across the streets of Vienna, preferring air lines to conductors laid in the earth. In 1837, Schilling ordered at a rope manufactory in St. Petersburg the necessary length of an insulated submarine cable, for the purpose of connecting telegraphically that capital with Cronstadt, through a portion of the Gulf of Finland; the distance between the two cities being twenty miles. His death which occurred August 7, 1837, arrested the enterprise.

§ *Lehrbuch des Galvanismus*, etc. by G. F. Fechner, 8vo. Leipzig, 1829, p. 269.

|| *The Quarterly Journal* of the Roy. Inst. of Gr. Brit. Mar. 1830, vol. xxix, p. 185.

marvelous progeny. In the same year, 1820, Dominique François Arago, of Paris, announced, "On repeating the experiments of the Danish physicist, I have observed that the same current will *develop* strongly in strips of iron or steel, the magnetic power. . . . The conjunctive wire communicates to soft iron but a momentary magnetization; but to small pieces of steel it gives frequently a permanent magnetism. I have been able thus to completely magnetize sewing-needles."*

This germ of a new power required, as usual, the successive labors of more than one philosophic investigator to develop fully its capacities. To William Sturgeon, of Woolwich, England, belongs the distinguished honor (too little appreciated by his countrymen) of giving to the scientific toy of Arago a suitable form, and thus of first producing in 1824, the true electro-magnet with its intermittent control of an armature. Dispensing with the glass tube of Arago, Sturgeon constructed a horse-shoe bar of soft iron (after the form of the usual permanent magnet), which he coated with a non-conducting resinous varnish. Then winding a copper wire in a loose coil directly about the limbs of the horse-shoe, on bringing the ends of the wire in connection with the poles of a single galvanic pair of moderate size, he found his temporary magnet capable of sustaining several pounds by its armature; and on breaking the circuit, becoming instantly powerless.

It resulted from the correlative function of the galvanic current in directing transversely a permanently magnetized needle (first discovered by Romagnosi and Oersted), or in inducing temporary magnetism in iron thus transversely placed (first discovered by Arago and Sturgeon), that two distinct methods of signaling were offered by this new agency, accordingly as a permanent or a temporary magnet were employed. In the former case, the determined oscillations of the *magnetic bar*, by means of intermittent currents in a surrounding coil, would form the indicating device; and in the latter case, the determined oscillations of the *armature*, by means of intermittent currents in the coil surrounding its associated magnet, would give the indication. Hence the two types of electro-magnetic telegraph; the magnetic-needle system, and the magnetic-armature system.†

On experimenting with the galvanometer needle, it was very soon discovered that it responded only to variations of surface action in a single pair of galvanic elements, and that a large number of galvanic cells (as in the Cruickshanks battery), having even a greater total surface of oxi-

* *Annales de Chimie et de Physique*, 1820, vol, xv, pp. 93, 95, Arago's method of experimentation consisted in winding the wire connecting the poles of the battery, around a glass tube in a loose helix, within which tube small pieces of iron or steel were placed. Sir Humphrey Davy, of England, not long afterward, also magnetized steel-needles by galvanism; and even effected the result with ordinary electricity from a Leyden-jar battery. (*Annals of Philosophy*, August, 1821, vol. ii, n. s. pp. 81–88.) This was the germ—though scarcely more than the germ—of the electro-magnet. For a notice of early anticipations of electro-magnetism, see "Supplement," NOTE C.

† A modification of the latter system, by which the oscillations of an armature are superseded by the variable attraction between the magnetized core and its hollow galvanic coil, might perhaps be considered as forming a third type—that of the "axial" magnet. This has been employed in House's printing telegraph.

dation, produced but a comparatively small declination of Schweigger's needle. In fact, no multiplication of galvanic elements was successful in increasing the deflection of a given galvanometer. On the other hand, the same galvanometer was found to have its deflections greatly reduced with every increase in the length of the interposed circuit. And here again an increase of surface in the galvanic pair failed to overcome the increased resistance of a lengthened conductor. There was also an early limit found to the number of turns in the galvanometer coil, which could be efficiently employed with any given surface of oxidizable metal in the single galvanic element.

In 1824, Peter Barlow, the eminent English mathematician and magnetician, taking up Ampère's suggestion, endeavored more fully to test its practicability. He has thus stated the result: "In a very early stage of electro-magnetic experiments, it had been suggested that an instantaneous telegraph might be established by means of conducting wires and compasses. The details of this contrivance are so obvious, and the principle on which it is founded so well understood, that there was only one question which could render the result doubtful; and this was, is there any dimunition of effect by lengthening the conducting wire? It has been said that the electric fluid from a common [tin-foil] electrical battery had been transmitted through a wire four miles in length without any sensible diminution of effect, and to every appearance instantaneously; and if this should be found to be the case with the galvanic circuit, then no question could be entertained of the practicability and utility of the suggestion above adverted to. I was therefore induced to make the trial; but I found such a sensible diminution with only 200 feet of wire, as at once to convince me of the impracticability of the scheme. It led me however to an inquiry as to the cause of this diminution and the laws by which it is governed."*

From the rapid reduction of effect observed with increasing lengths of conjunctive wire under the conditions tried, Barlow (from a considerable series of experimental results) was led to believe that the resistance of the conducting wire is approximately proportional to the square root of its length.†

Notwithstanding therefore Ampère's "completely successful" experiment "through a very long conducting wire" and Schilling's later working of his telegraph "through a great length of wires," (the precise length of the circuit not being stated in either case,) the problem of the electro-magnetic telegraph could hardly be considered as satisfactorily solved for any practical purposes of communicating to great distances. In the deliberate judgment of one of the most eminent of English phys-

* "On the laws of electro-magnetic action." *Edinburgh Philosophical Journal*, Jan. 1825, vol. xii, p. 105.

† Pp. 110, 111 of the Journal just cited. Later experiments under varied conditions have shown that Ohm's law (announced three years after Barlow's) of a simple ratio of resistance to length is approximately correct.

icists in this special department, careful experiment only tended to show "the impracticability of the scheme."

It is at this point that there appears a new explorer in the electro-magnetic field; a field from which apparently all the laurels had been already gathered. Joseph Henry, elected to the professorship of mathematics and natural philosophy in the Albany Academy, of New York, in 1826, commenced very shortly afterward his scientific investigations. Sturgeon, in 1824, had pointed out the proper manner of making an "electro-magnet," and had also greatly improved lecture-room apparatus for illustrating the torsional reaction between a permanent magnet and a galvanic circuit when either is made movable. By introducing in such cases a larger and more powerful magnet he had succeeded in exhibiting the usual phenomena on a larger scale with a considerable reduction of the battery power.*

Henry was enabled by his skillful experimental investigations to exhibit all the class illustrations attempted by Sturgeon, not only on a still larger and more conspicuous scale, with the use of feeble magnets (where required), but with a still further reduction of the battery power. And he moreover carried out the same results to other cases where an artificial magnet is inapplicable, as for example, in the illustration of Ampère's fine discovery of the mutual action of two electric currents on each other, or of the influence of the terrestrial magnetism on a current, as in Ampère's swinging galvanic ring, or the floating ring of De La Rive. These very striking and unexpected results were obtained by the simple expedient of adopting in every case where single circuits had previously been used, the manifold coil of fine wire which Schweigger had employed to increase the sensibility of the galvanometer.

The coils employed by Henry in the various articles of apparatus thus improved, comprised usually about twenty turns of fine copper wire wound with silk to prevent metallic contact, the whole being closely bound together. To exhibit for instance Ampère's ingenious and delicate experiment showing the directive action of the earth as a magnet on a galvanic current when its conductor is free to move, (usually a small wire frame or ring, of a few inches in diameter, with its extremities dipping either into mercury cups or into mercury channels,) the effect was strikingly enhanced by Henry's method of suspending by a silk thread a large circular coil, 20 inches in diameter, of many wire circuits bound together with ribbon,—the extremities of the wire protruding at the lower part of the hoop, and soldered to a pair of small galvanic plates;—when by simply placing a tumbler of acidulated water beneath, the hoop

* *Transactions of the Society for the encouragement of Arts*, etc. 1825, vol. xliii, pp. 38-52. Sturgeon's battery (of a single element) consisted "of two fixed hollow concentric cylinders of thin copper, having a movable cylinder of zinc placed between them. Its superficial area is only 130 square inches, and it weighs no more than 1 lb. 5 oz." Mr. Sturgeon was deservedly awarded the silver medal of the Society for the Encouragement of Arts, &c. "for his improved electro-magnetic apparatus." The same is described also in the *Annals of Philosophy*, Nov. 1826, vol. xii, n. s. pp. 357-361.

at once assumed (after a few oscillations) its equatorial position transverse to the magnetic meridian. Such was the character of demonstration by which the new Professor was accustomed to make visible to his classes the principles of electro-magnetism. And it is safe to say that in simplicity, efficiency, and conspicuous distinctness, such apparatus for the lecture-room was far superior to any of the kind then existing.

The details of this early contribution to electrical science were set forth in a communication read by Henry before the Albany Institute October 10, 1827, "On some modifications of the electro-magnetic apparatus." In this paper he remarks:

"Mr. Sturgeon, of Woolwich, who has been perhaps the most successful in these improvements, has shown that a strong galvanic power is not essentially necessary even to exhibit the experiments on the largest scale. . . . Mr. Sturgeon's suite of apparatus, though superior to any other as far as it goes, does not however form a complete set; as indeed it is plain that his principle of strong magnets cannot be introduced into every article required, and particularly into those intended to exhibit the action of the earth's magnetism on a galvanic current, or the operation of two conjunctive wires on each other. To form therefore a set of instruments on a large scale that will illustrate all the facts belonging to this science, with the least expense of galvanism, evidently requires some additional modification of the apparatus, and particularly in those cases in which powerful magnets cannot be applied. And such a modification appears to me to be obviously pointed out in the construction of Professor Schweigger's galvanic 'multiplier'; the principles of this instrument being directly applicable to all the experiments in which Mr. Sturgeon's improvement fails to be useful."*

Should any one be disposed to conclude that this simple extension of Schweigger's multiple coil was unimportant and unmeritorious, the ready answer occurs, that talented and skillful electricians, laboring to attain the result, had for six years failed to make such an extension. Nor was the result by any means made antecedently assured by Schweigger's success with the galvanometer. If Sturgeon's improvement of economizing the battery size and consumption, by increasing the magnet factor (in those few cases where available), was well deserving of reward, surely Henry's improvement of a far greater economy, by increasing the circuit factor (entirely neglected by Sturgeon), deserved a still higher applause.

In a subsequent communication to Silliman's Journal, Henry remarks on the results announced in October, 1827: "Shortly after the publication mentioned, several other applications of the coil, besides those described in that paper, were made in order to increase the size of electro-magnetic apparatus, and to diminish the necessary galvanic power. The most interesting of these was its application to a development of magnetism in soft iron, much more extensive than to my knowledge had been

* *Transactions of the Albany Institute*, vol. i, pp. 22, 23.

previously effected by a small galvanic element." And in another later paper, he repeated to the same effect: "After reading an account of the galvanometer of Schweigger, the idea occurred to me that a much nearer approximation to the theory of Ampère could be attained by insulating the conducting-wire itself, instead of the rod to be magnetized; and by covering the whole surface of the iron with a series of coils in close contact."

The electro-magnet figured and described by Sturgeon (in his communication of November, 1825,) consisted of a small bar or stout iron wire bent into a ∩ or horse-shoe form, having a copper wire wound loosely around it in eighteen turns, with the ends of the wire dipping into mercury-cups connected with the respective poles of a battery having 130 square inches of active surface. This was undoubtedly the most efficient electro-magnet then in existence.

In June of 1828, Henry exhibited to the Albany Institute a small-sized electro-magnet closely wound with silk-covered copper wire about one-thirtieth of an inch in diameter. By thus insulating the conducting wire, instead of the magnetic bar or core, he was enabled to employ a compact coil in close juxtaposition from one end of the horse-shoe to the other, obtaining thereby a much larger number of circuits, and with each circuit more nearly at right angles with the magnetic axis. The lifting power of this magnet is not stated, though it must obviously have been much more powerful than the one described by Sturgeon.

In March of 1829, Henry exhibited to the Institute a somewhat larger magnet of the same character. "A round piece of iron about one-quarter of an inch in diameter was bent into the usual form of a horse-shoe, and instead of losely coiling around it a few feet of wire, as is usually described, it was tightly wound with 35 feet of wire covered with silk, so as to form about 400 turns; a pair of small galvanic plates which could be dipped into a tumbler of diluted acid, was soldered to the ends of the wire, and the whole mounted on a stand. With these small plates the horse-shoe became much more powerfully magnetic than another of the same size and wound in the usual manner, by the application of a battery composed of 28 plates of copper and zinc each 8 inches square." In this case the coil was wound upon itself in successive layers.

To Henry, therefore, belongs the exclusive credit of having first constructed the magnetic "spool" or "bobbin," that form of coil since universally employed for every application of electro-magnetism, of induction, or of magneto-electrics.

In the latter part of 1829, Henry still further increased the magnetic power derived from a single galvanic pair of small size, by a new arrangement of the coil. "It consisted in using several strands of wire each covered with silk, instead of one." Employing a horse-shoe formed from a cylindrical bar of iron half an inch in diameter and about ten inches long, wound with 30 feet of tolerably fine copper wire, he found that with a current from only two and a half square inches of zinc, the magnet held 14 pounds.* Winding upon its arms a second wire of the same length (30 feet) whose ends were similarly joined to the same galvanic pair, the magnet lifted 28 pounds. On these results he remarks:

"These experiments conclusively proved that a great development of magnetism could be effected by a very small galvanic element, and also that the power of the coil was materially increased by multiplying the number of wires, without increasing the length of each. The multiplication of the wires increases the power in two ways: first, by conducting a greater quantity of galvanism, and secondly, by giving it a more proper direction; for since the action of a galvanic current is directly at right angles to the axis of a magnetic needle, by using several shorter wires we can wind one on each inch of the length of the bar to be magnetized, so that the magnetism of each inch will be developed by a separate wire. In this way the action of each particular coil becomes directed very nearly at right angles to the axis of the bar, and consequently the effect is the greatest possible. This principle is of much greater importance when large bars are used. The advantage of a greater conducting power from using several wires might in a less degree be obtained by substituting for them one large wire of equal sectional area; but in this case the obliquity of the spiral would be much greater, and consequently the magnetic action less."†

But in the following year, 1830, Henry pressed forward his researches to still higher results. Assisted by his friend Dr. Philip Ten-Eyck, he proceeded to test the power of electro-magnetic attraction on a larger scale. "A bar of soft iron 2 inches square and 20 inches long was bent into the form of a horseshoe 9½ inches high; (the sharp edges of the bar were first a little rounded by the hammer;) it weighed 21 pounds. A piece of iron from the same bar, weighing 7 pounds, was filed perfectly flat on one surface for an armature or lifter. The extremities of the legs of the horse-shoe were also truly ground to the surface of the armature. Around this horse-shoe 540 feet of copper bell-wire were wound in nine coils of 60 feet each; these coils were not continued around the whole length of the bar, but each strand of wire (according to the principle before mentioned) occupied about two inches and was coiled several times backward and forward over itself. The several ends of the wires were left projecting, and all numbered, so that the first and the last end of each strand might be readily distinguished. In this manner we formed an experimental magnet on a large scale, with which several combinations of wire could be made by merely uniting the different projecting ends. Thus if the second end of the first wire be soldered to the first end of the second wire, and so on through all the series, the whole will form a continued coil of one long wire. By solder-

*It must not be forgotten that at the time when this experimental magnet was made, the strongest electro-magnet in Europe was that of Sturgeon, capable of supporting 9 pounds, with 130 square inches of zinc surface in the battery.

†Silliman's *Am. Journal of Science*, Jan. 1831, vol. xix, p. 402.

ing different ends, the whole may be formed into a double coil of half the length, or into a triple-coil of one-third the length, &c. The horse-shoe was suspended in a strong rectangular wooden-frame 3 feet 9 inches high and 20 inches wide."

Two of the wires (one from each extremity of the legs) being joined together by soldering, so as to form a single circuit of 120 feet, with its extreme ends connected with the battery, produced a lifting-power of 60 pounds. (Experiment 19.) The same two wires being separately connected with the same battery (forming a double circuit of 60 feet each), a lifting-power of 200 pounds was obtained, (Experiment 10,) or more than three times the power of the former case with the same wire. Four wires (two from each extremity of the legs) being separately connected with the battery (forming four circuits) gave a lifting-power of 500 pounds. (Experiment 12.) Six wires (three from each leg) united in three pairs (forming three circuits of 180 feet each) gave a lifting-power of 290 pounds. (Experiment 18.) The same six wires being separately connected with the battery in six independent circuits, produced a lifting-power of 570 pounds, (Experiment 13,) or very nearly double that of the same wires in double-lengths. When all the nine wires were separately attached to the battery a lifting-power of 650 pounds was evoked. (Experiment 14.) In all these experiments "a small single battery was used, consisting of two concentric copper cylinders, with zinc between them; the whole amount of zinc-surface exposed to the acid from both sides of the zinc was two-fifths of a square foot; the battery required only half a pint of dilute acid for its submersion."

"In order to ascertain the effect of a very small galvanic element on this large quantity of iron, a pair of plates *exactly one inch square* was attached to all the wires; the weight lifted was 85 pounds." (Experiment 16.) For the purpose of obtaining the maximum attractive power of this magnet, with its nine independent coils, "a small battery formed with a plate of zinc 12 inches long and 6 wide, and surrounded by copper, was substituted for the galvanic element used in the former experiments: the weight lifted in this case was 750 pounds." (Experiment 15.) *

Although not directly connected with the purpose of this exposition,

* Silliman's *Am. Jour. Sci.* same vol. pp. 404, 405. The only European physicist who at this period had obtained any magnetic results even *approaching* those effected by Henry, was Dr. Gerard Moll (professor of natural philosophy in the University of Utrecht), who having seen in England in 1828 an electro-magnet of Sturgeon's which supported nine pounds (the very year in which Henry had exhibited a much more powerful magnet before the Albany Institute); "determined to try the effect of a larger galvanic apparatus"; and in 1830 remarked, "I obtained results which appear astonishing." Having formed a horse-shoe about twelve and a half inches in height, of a round bar of iron two and a quarter inches in diameter, he surrounded it with about 26 feet of insulated copper wire one-eighth of an inch thick, in a tolerably close coil of 44 turns. The weight of the whole was about 26 pounds; and with the current from a galvanic pair of about 11 square feet of zinc surface, the magnet sustained a weight of 154 pounds. (Brewster's *Edinburgh Journal of Science*, Oct., 1830, vol. iii, n. s. p. 214.) Henry's magnet less in size and weight, lifted about five times this load, with only one-eleventh of Moll's battery surface.

it may be added here that in the following year, 1831, Henry constructed for the laboratory of Yale College a magnet about one foot high from a three inch octagonal bar of iron thirty inches long, which wrapped with twenty-six strands of copper wire and excited by a battery surface of about five square feet, supported 2,300 pounds. Professor Silliman wrote on this occasion, "He has the honor of having constructed by far the most powerful magnets that have ever been known; and his last, weighing (armature and all) but 82½ pounds, sustains over a ton. It is eight times more powerful than any magnet hitherto known in Europe."* And Sturgeon (if not the real father, at least the true foster-father, of the electro-magnet), with a generous enthusiasm, remarked: "Professor Henry has been enabled to produce a magnetic force which totally eclipses every other in the whole annals of magnetism; and no parallel is to be found since the miraculous suspension of the celebrated oriental impostor in his iron coffin."†

But to return to his investigations of 1830, Henry, after finding that the highest attractive power of the magnet was developed by his novel artifice of multiple coils, proceeded to experiment with the simple spool magnet of long continuous single coil; and his researches were rewarded by a new discovery, namely that though the former method of winding the magnet produced the strongest attraction, the latter arrangement (under special conditions) permitted the weaker attractive power to be exercised at a far greater distance; that is through a much greater length of conducting wire.

Employing his earlier and smaller magnet of 1829, formed of a quarter-inch rod, but wound with about 8 feet of copper wire, he tried the effects of different battery powers, of different length of circuits, and of different lengths of coil upon the magnet. Excited with a single pair, "composed of a piece of zinc plate 4 inches by 7, surrounded with copper" (about 56 square inches of zinc surface), the magnet sustained four and a half pounds. (Experiment 4.) With about 500 feet of insulated copper wire (.045 of an inch in diameter) interposed between the battery and the magnet, its lifting-power was reduced to two ounces; (Experiment 5;) or about 36 times. With double this length of wire (or a little over 1,000 feet) interposed, the lifting-power of the magnet was only half an ounce; (Experiment 4;) thus fully confirming the results obtained by Barlow with the galvanometer; and showing that the same conditions of enfeebled action with increasing length of circuit applied equally to the magnet. With a small galvanic pair 2 inches square, acting through the same length of wire, (over 1,000 feet,) "the magnetism was scarcely observable in the horse-shoe." (Experiment 3.)

Employing next a trough battery of 25 pairs, having the same zinc surface as previously, the magnet in direct connection, (which before had supported four and a half pounds,) now lifted but seven ounces; not

*Silliman's *Am. Jour. Sci.* April, 1831, vol. xx, p. 201.

†*Philosophical Magazine; and Annals*, March, 1832, vol. xi, p. 199.

quite half a pound. But with the 1,060 feet of copper wire (a little more than one fifth of a mile) suspended several times across the large room of the academy, and placed in the galvanic circuit, the same magnet sustained eight ounces: (Experiment 7:) that is to say, the current from the galvanic trough produced greater magnetic effect through this length of wire, than it did without it.

"From this experiment it appears that the current from a galvanic trough is capable of producing greater magnetic effect on soft iron after traversing more than one-fifth of a mile of intervening wire than when it passes only through the wire surrounding the magnet. It is possible that the different states of the trough with respect to dryness may have exerted some influence on this remarkable result; but that the effect of a current from a trough if not increased is but slightly diminished in passing through a long wire is certain." And after speculating on this new and at the time somewhat paradoxical result, Henry concludes: "But be this as it may, the fact that the magnetic action of a current from a *trough* is at least not sensibly diminished by passing through a long wire, is directly applicable to Mr. Barlow's project of forming an electro-magnetic telegraph;* and it is also of material consequence in the construction of the galvanic coil. From these experiments it is evident that in forming the coil we may either use one very long wire, or several shorter ones, as the circumstances may require: in the first case, our galvanic combination must consist of a number of plates so as to give 'projectile' force; in the second, it must be formed of a single pair."†

The importance of this discovery can hardly be overestimated. The magnetic "spool" of fine wire, of a length—tens and even hundreds of times that ever before employed for this purpose,—was in itself a gift to science, which really forms an epoch in the history of electro-magnetism. It is not too much to say that almost every advancement which has been made in this fruitful branch of physics since the time of Sturgeon's happy improvement, from the earliest researches of Faraday downward, have been directly indebted to Henry's magnets.‡ By means of the Henry "spool" the magnet almost at a bound was developed from a feeble childhood to a vigorous manhood. And so rapidly and generally was the new form introduced abroad among experimenters, few of whom had ever seen the papers of Henry, that probably very few indeed have been

* Really Ampère's project, not Barlow's. In a subsequent paper Henry corrected this allusion by saying, "I called it 'Barlow's project,' when I ought to have stated that Mr. Barlow's investigation merely tended to disprove the possibility of a telegraph."

† Silliman's *Am. Jour. Sci.* Jan. 1831, vol. xix, pp. 403, 404.

‡ Both forms of the Henry magnet have found valuable applications in science. In Faraday's first electrical investigations, in the latter part of 1831, he acknowledged the merit of Henry's magnets, and in constructing his duplex helices for observing the phenomena of induction, he adopted Henry's method of winding 12 coils of copper wire each 27 feet long, one upon the other. (*Philosophical Transactions of the Royal Society*, November 24, 1831, vol. cxxii [for 1832], pp. 126 and 138. And Faraday's *Experimental Researches*, etc. vol. i, art. 6, p. 2, and art. 57, p. 15.)

aware to whom they were really indebted for this familiar and powerful instrumentality. But the historic fact remains, that prior to Henry's experiments in 1829, no one on either hemisphere had ever thought of winding the limbs of an electro-magnet on the principle of the "bobbin," and not till after the publication of Henry's method in January of 1831, was it ever employed by any European physicist.*

But in addition to this large gift to science, Henry (as we have seen) has the pre-eminent claim to popular gratitude of having first practically worked out the differing functions of two entirely different kinds of electro-magnet: the one surrounded with numerous coils of no great length, designated by him the "quantity" magnet, the other surrounded with a continuous coil of very great length, designated by him the "intensity" magnet.† The former and more powerful system, least affected by an "intensity" battery of many pairs, was shown to be most responsive to a single galvanic element: the latter and feebler system, least influenced by a single pair, was shown to be most excited by a battery of numerous elements; but at the same time was shown to have the singular capability (never before suspected nor imagined) of subtile excitation from a distant source. Here for the first time is experimentally established the important principle that there must be a proportion between the aggregate internal resistance of the battery and the whole external resistance of the conjunctive wire or conducting circuit; with the very important practical consequence, that by combining with an "intensity" magnet of a single extended fine coil an "intensity" battery of many small pairs, its electro-motive force enables a very long conductor to be employed without sensible diminution of the effect.‡ This was a very important though unconscious experimental confirmation of the mathematical theory of Ohm, embodied in his formula expressing the relation between electric flow and electric resistance, which though propounded two or three years previously, failed for a long time to attract any attention from the scientific world.§

* Henry's "spool" magnet appears to have been introduced into France by Pouillet in 1832. See "Supplement," NOTE D.

† "In describing the results of my experiments the terms 'intensity' and 'quantity' magnets were introduced to avoid circumlocution, and were intended to be used merely in a technical sense. By the *intensity* magnet I designated a piece of soft iron so surrounded with wire that its magnetic power could be called into operation by an 'intensity' battery; and by a *quantity* magnet, a piece of iron so surrounded by a number of separate coils that its magnetism could be fully developed by a 'quantity' battery." (*Smithsonian Report* for 1857, p. 103.) These terms though generally discarded by recent writers, are still very convenient designations of the two classes of action, both in the battery and in the magnet.

‡ Beyond a certain maximum length, there is of course a decrease of power for each differing coil of the "intensity" magnet, proportioned to the increased resistance of a long conductor; but the magnetizing effect has not been found to be diminished in the ratio of its length. In a very long wire, the magnetizing influence (with a suitable "intensity" battery) appears to be inversely proportioned to the square of the length of the conductor.

§ Georg Simon Ohm, professor in physics at Munich, published at Berlin, in 1827, his "Galvanische Kette, mathematisch bearbeitet:" and in the following year, he published a supplementary paper entitled "Nachträge zu seiner mathematischen Bearbeitung der galvanischen Kette;" in Kastner's *Archiv für gesammte Naturlehre:*

Never let it be forgotten that he who first exalted the "quantity" magnet of Sturgeon from a power of twenty pounds to a power of twenty hundred pounds, was the absolute CREATOR of the "intensity" magnet; that magnet which alone is able to act at a great distance from its exciting battery;—that magnet which by very reason of its lower "quantity" is alone applicable to the uses of telegraphy.

As Professor Daniell has concisely stated the problem: "Electro-magnets of the greatest power, even when the most energetic batteries are employed, utterly cease to act when they are connected by considerable lengths of wire with the battery."*

Seven years after Henry's first experimental demonstration of this unlooked-for result, and his complete establishment of the conditions required for magnetizing iron at great distances through very long conducting wires, Prof. Charles Wheatstone, of King's College, London, having found a difficulty in signaling through four miles of wire, was enabled to work out the problem for his own telegraph, by help derived from Henry's labors. And yet he permitted his colleague, Prof. John F. Daniell, of King's College, to prefix to the passage above quoted from the excellent treatise on "Chemical Philosophy," the remarkable statement: "Ingenious as Professor Wheatstone's contrivances are, they would have been of no avail for telegraphic purposes without the investigation, *which he was the first to make*, of the laws of electro-magnets, when acted on through great lengths of wire." And this erroneous declaration was published long after Henry's "quantity" and "intensity" magnets had been employed in the experiments of European electricians; and years after Professor Wheatstone himself had formed the acquaintance of Henry, and in April, 1837, had learned from his own lips an account of his elaborate investigations and successful results.†

Whether Baron Schilling ever experimented on a sufficient length of circuit to encounter the fundamental practical difficulty announced by Barlow in 1825 does not appear; but that formidable obstacle to the actual extension of his enterprise, certainly existed until the year 1831, when Henry announced that the principles demonstrated by his researches in 1829 and 1830, were "directly applicable to the project of forming an electro-magnetic telegraph." And while these principles

(8vo. Nürnberg:) 1828, vol. xiv, pp. 475–493. Fourteen years after the publication of the former memoir, this elaborate discussion was for the first time translated into English, by Mr. William Francis. ("The Galvanic Circuit investigated mathematically." Taylor's *Scientific Memoirs*, etc. London, 1841, vol. ii, pp. 401–506.)

* *Introduction to the Study of Chemical Philosophy*, second edition, 8vo. London, 1843, chap. xvi, sect. 859, p. 576.

† *Smithsonian Report* for 1857, pp. 111, 112. The following pertinent extract is made from an excellent and appreciative memoir of the "Life and Work of Joseph Henry," recently read at the annual session of the American Electrical Society, at Chicago, Ill., December 12, 1878, by one of its vice-presidents, Mr. Frank L. Pope: "In 1856, referring again to these experiments, Wheatstone writes: 'With this law and its applications, *no persons in England*, who had before occupied themselves with experiments relating to electric telegraphs, had been acquainted.' . . . It would seem from the peculiar wording of Wheatstone's statement last quoted, that he must then have been aware of Henry's priority in this respect, and had his experiments in mind, at the time of writing it." (*Journal of the Am. Electrical Society*, vol. ii, pp. 135, 136.) This subject is more fully considered in the "Supplement," NOTE F.

underlie all subsequent applications of the intermittent magnet, they form indeed the indispensable basis of every form of the electro-magnetic telegraph since invented. They settled satisfactorily (in Barlow's phrase) the "only question which could render the result doubtful"; and though derived from the magnet, were obviously as applicable to the galvanometer needle.*

It is idle to say in disparagement of these successes, that in the competitive race of numerous distinguished investigators in the field, diligently searching into the conditions of the new-found agency, the same results would sooner or later have been reached by others. For of what discovery or invention may not the same be said? Only those who have sought in the twilight of uncertainty, can appreciate the vast economy of effort by prompt directions to the path from one who has gained an advance. Not for what might be, but for the actual bestowal, does he who first grasps a valuable truth merit the return of at least a grateful recognition.

1831. As an experimental demonstration of the telegraph—now made possible, Joseph Henry, early in the year 1831, suspended around the walls of one of the upper rooms in the Albany Academy, a mile of copper bell-wire interposed in a circuit between a small Cruickshanks battery and an "intensity" magnet. A narrow steel rod (a permanent magnet) pivoted to swing horizontally like the compass needle, was arranged so that one end remained in contact with a limb of the soft iron core, while near the opposite end of the compass rod a small stationary office-bell was placed. At each excitation of the electro-magnet, the compass rod or needle was repelled from one limb (by its similar magnetism) and attracted by the other limb, so that its free end tapped the bell. On reversing the current, the compass rod moved back to the opposite limb of the electro-magnet. This simple device the Professor was accustomed to exhibit to his classes at the academy, during the years 1831 and 1832, in illustration of the facility of transmitting signals to a distance by the prompt action of electro-magnetism.†

This memorable experimental telegraphic arrangement involved three very significant and important novelties. In the first place, it was the first electro-magnetic telegraph employing an "intensity" magnet ca-

* When urged by a zealous friend to secure an early patent on these valuable and pregnant improvements, Henry resolutely withstood every importunity, seeming to feel that a discoverer's position and aptitude are lowered by courting self-aggrandizement from scientific truth; a self-denying generosity which characterized him throughout his life. While such disinterestedness cannot fail to excite our admiration, it may perhaps be questioned whether in this case it did not, from a practical point of view, amount to an over-fastidiousness; whether such legal establishment of ownership, shielding the possessor from the occasional depreciations of the envious, and securing by its more tangible remunerations the leisure and the means for more extended researches, would not have been to science more than a compensation for the supposed sacrifice of dignity by the philosopher. Since the date of the American patents of Wheatstone and of Morse (ten years later) several hundred patents have been granted in this country for ingenious improvements upon or modifications of the electro-magnetic telegraph, all of them necessarily dependent on Henry's original invention.

† For the testimonials of a few surviving eye-witnesses to the practical working of Henry's experimental line in 1831, and 1832, see "Supplement," NOTE E.

pable of being excited at very great distances from a suitable "intensity" battery. And there can be no doubt that a similar combination of "intensity" battery, with a very long coil galvanometer (such as had previously been found inoperative), was alone wanting to have rendered the early telegraph of Schilling a popular and commercial success.

In the second place, this experimental arrangement of Henry was the first electro-magnetic telegraph employing the armature as the signaling device; or employing the *attractive* power of the intermittent magnet, as distinguished from the *directive* action of the galvanic circuit. That is to say, it was strictly speaking the first "*magnetic* telegraph."

In the third place, it was the first *acoustic* electro-magnetic telegraph. One practical inconvenience of the "needle" system has been found to be the perfect silence of its indications; and hence in almost every case a call-alarm has been required to insure attention to its messages. In this respect the intermittent magnet presents the advantage, not merely of a greater mechanical power from the same galvanic current, and thus of a better adaptation for striking a bell at a distance, but of being in itself an audible sounder by the mere impacts of its armature.*

It is suggestive to consider for a moment how different would have been the popular estimate of Henry's labors, (and especially the *practical* estimation of subsequent patentees), if the modest discoverer and inventor had been "worldly-wise" enough to secure an early patent on these three indisputably original and most pregnant features of telegraphy:—to contest which no rival has ever appeared.†

In 1832, Henry was elected to the chair of natural philosophy in the college of New Jersey, at Princeton. In 1834, he constructed for the laboratory of this college an original and ingenious form of galvanic battery, comprising eighty-eight elements, (each having an active zinc surface of one and a half square feet,) of which any number, from a single pair upward, could be brought into action; while by means of adjustable

* It may be incidentally mentioned that early in 1831, after the satisfactory operation of the first telegraphic magnet, Henry contrived the first Electro-magnetic Engine, comprising an oscillating horizontal electro-magnetic bar, just below each end of which was secured an upright permanent magnet, the two having similar poles. The polarity of the oscillating electro-magnet was reversed at the moment of attractive contact, by automatically inverting the circuit current, and thus each of its poles was alternately attracted and repelled by its neighboring magnet. (Silliman's *Am. Journal of Science*, July, 1831, vol. xx, pp. 340–343.) Henry was therefore the original inventor of the automatic pole-changer or commutator,—a device having a very wide range of useful application. The illustrious English physicist, James P. Joule, in his "Historical Sketch of the rise and progress of Electro-magnetic Engines for propelling machinery," remarks: "The improved plan by Professor Henry of raising the magnetic action of soft iron, developed new and inexhaustible sources of force which appeared easily and extensively available as a mechanical agent; and it is to the ingenious American philosopher, that we are indebted for the first form of a working model of an engine upon the principle of reciprocating polarity of soft iron by electro-dynamic agency." (Sturgeon's *Annals of Electricity*, etc. March, 1839, vol. iii, p. 430.)

† A quarter of a century afterward Henry could proudly say, "I have sought no patent for inventions, and solicited no remuneration for my labors, but have freely given their results to the world; expecting only in return to enjoy the consciousness of having added by my investigations to the sum of human knowledge, and to receive the credit to which they might justly entitle me." (*Smithsonian Report* for 1857, p. 86.)

conductors, all the positive elements could be associated together, as also all the negative ones, so as to form virtually a single pair having 132 square feet of zinc surface, or any smaller area desired. In this manner the apparatus could readily be transformed into a "quantity" battery, or an "intensity" battery, at pleasure. In the same year he constructed for the laboratory a powerful "quantity" magnet, surpassing his Yale College magnet; its lifting power, with a battery not exceeding one cubic foot in bulk, being 3,500 pounds. In the following year, 1835, he extended wires across the front campus of the college grounds, from the upper story of the library building to the philosophical hall on the opposite side, through which magnetic signals were occasionally sent, distinguished by the number of taps on the bell, as first exhibited by him four or five years earlier in the hall of the Albany Academy. Although Henry had established the fact (contrary to all the antecedent expectation of physicists) that the most powerful form of magnet—the "quantity" magnet—is not the form best adapted to distant action through an extended circuit, the ingenious idea occurred to him that he could easily combine such a system with the feebler "intensity" system, so as to produce powerful mechanical action at almost any required distance. It was simply necessary to apply to the oscillating armature of the distant "intensity" magnet a suitable prolongation so arranged as to open and close the short circuit of the adjoining "quantity" magnet of any available power. It was with his Princeton telegraph line, and its comparatively feeble magnet, that he undertook the experiment of breaking by the mere lift of a small wire from a mercury thimble the "quantity" circuit of his monster magnet, and thus causing its heavy load to fall:—a force scarcely safe if exerted through any sensible distance. He thus fully illustrated the practicability of calling into action at a great distance a power capable of producing the most energetic mechanical effects.*

1833. Ten years after the experimental telegraph of Schilling, Professors Carl Friedrich Gauss and Wilhelm Edward Weber constructed at Göttingen a galvanometer telegraph of single circuit from the Cabinet of Natural Philosophy to the Observatory, a distance of about a mile and a half. The two naked wires after the method of Weber were carried over the houses and steeples of Göttingen, being supported by insulators. The battery power being small, the receiving apparatus consisted of a "multiplier" containing a very great length of fine silvered copper wire; and the magnetic bar suspended by a silk thread carried on the axis of suspension a small mirror, whose minute deflections were observed at the distance of ten or twelve feet through a telescope.† The tele-

Smithsonian Report for 1857, pp. 106, 112.

† This appears to be one of the first employments of a reflecting galvanometer, an instrument which in the hands of Sir William Thomson has been brought to an extreme degree of sensibility, and has rendered ocean telegraphy possible. As early as 1826, however, Prof. Christian J. Poggendorff applied the reflector to the magnetic needle for accurately determining minute variations in its horizontal declination. (Pogg. *Annalen der Phys. und Chem.* 1826, vol. vii. pp. 121–130.)

graph was first worked by a galvanic current from a battery, and afterward for convenience by the secondary current from a magneto-electric apparatus; to which Gauss adapted an arrangement of commutator, whereby the direction of the induced current could be instantly reversed by a touch of the finger. The alphabet of signs was made up of differing combinations of right and left deflections of the needle. Weber applied to the signaling device a delicate apparatus for setting off a clock alarm.*

1836. Prof. C. A. Steinheil, of Munich, at the request of Gauss, (who was absorbed in more abstract researches on magnetism,) in 1834, undertook to develop and improve his arrangement; and in 1836 had constructed a similar galvanometer telegraph line between Munich and Bogenhausen, a distance of about two miles. † Employing a greater power he arranged at the receiving station the magnetic bar or double bars of the galvanometer with a larger sweep, so that two bells of differing tones should be struck thereby; and he thus produced an acoustic telegraph (five years later than Henry's), capable of audible language, and dispensing with the occasion for any call-alarm. To the adjacent ends of the two magnetic bars having opposite polarities, but oscillating within the same coil, he applied fountain pens or marking-points so as to make permanent alternating dots on a fillet of paper carried under them by the regular movement of clock-work, in the manner long familiarly employed in self-registering meteorological and other instruments. Although Dyar, on Long Island, had devised a chemical register as early as 1828, and had partly executed it by a successful trial, this double magnet of Steinheil appears to constitute the earliest operative application of an automatic record to the electric, or to the electro-magnetic, telegraph. Steinheil also improved somewhat on the alphabet of Gauss, though adopting substantially the same system.‡

In the following year, 1837, he made another most important improvement in practical telegraphy, by the unexpected discovery that even the single circuit of a to and fro line could be further simplified by the suppression and economy of one-half of its wire.§

* *Göttingische Gelehrte Anzeigen*, Aug. 9, 1834, part ii, No. 128, pp. 1272, 1273. And *Polytechnisches Central-Blatt*, June, 1838, Jahrgang iv, No. 31, pp. 487–496.

† According to Dr. Hamel of St. Petersburg, in the early part of July, 1837, "Steinheil, at Munich, had completed the connection of his house in the Lerchenstrasse with the building of the Academy of Sciences, and with the Royal Observatory at Bogenhausen, by means of 36,000 feet of wire for conducting the current both ways, the wires being suspended in the air." (*Journal of Society of Arts*, July 29, 1859, vol. vii, p. 609.)

‡ Steinheil remarks: "As long as the intervals between the separate signs remain equal, they are to be taken together as a connected group, whether they be pauses between the tones, or intervals between the dots marked down. A longer pause separates these groups distinctly from each other. We are thus enable l, by appropriately selected groups thus combined, to form systems representing the letters of the alphabet, or stenographic characters, and thereby to repeat and render permanent at all parts of the chain where an apparatus like that above described is inserted, any information that we transmit. The alphabet that I have chosen represents the letters that occur the oftenest in German by the simplest signs." (Sturgeon's *Annals of Electricity*, etc. April, 1839, vol. iii, p. 520.)

§ "In 1837 Professor Steinheil operated a telegraph line between Munich and Bogen-

"Quite recently I made the discovery that the ground may be employed as one-half of the connecting chain. As in the case of frictional electricity, water or the ground may with the galvanic current form a portion of the connecting wire. Owing to the low conducting power of these bodies compared with metals, it is necessary that at the two places where the metal conductor is in connection with the semi-conductor, the former should present very large surfaces of contact. Taking water for instance to conduct two million times worse than copper, a surface of water proportional to this must be brought in contact with the copper, to enable the galvanic current to meet with equal resistance in equal distances of water and of metal; for instance, if the section of a copper wire is one-half of a square line, it will require a copper plate of 61 square feet of surface in order to conduct the galvanic current through the ground as the wire in question would conduct it: but as the thickness of the metal is quite immaterial in this case, it will be always within our reach to get the requisite surfaces of contact at no great expense. Not only do we by this means save half the conducting wire, but we can even reduce the resistance of the ground below what that of the wire would be, as has been fully established by experiments made here with the experimental telegraph."*

In his account of these valuable contributions to both the science and the art of electric telegraphy, Steinheil modestly assigns to his immediate predecessors the credit of the most important advancements in the system. He says: "To Gauss and Weber is due the merit of having, in 1833, actually constructed the first simplified galvano-magnetic telegraph. It was Gauss who first employed the excitement of induction [magneto-electricity], and who demonstated that the appropriate combination of a limited number of signs is all that is required for the transmission of communication.† Weber's discovery that a copper wire 7,460 feet long, which he had led across the houses and steeples at Göttingen, from the Observatory to the Cabinet of Natural Philosophy, required no special insulation, was one of great importance. The principle was thereby at once established of bringing the galvanic telegraph to the most convenient form. In accordance with the principles we have laid down, all that was required in addition to this was to render the signals audible; a task that apparently presented no very particular difficulty, inasmuch as in the very scheme itself a mechanical motion—namely the deflection of a

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hausen, in Germany, using iron wire conductors, and the earth for a return circuit. This discovery was published in 1837, in German, and translated into English by Julian Guggsworth, November 24, 1838." (Prescott's *Hist. Electr. Telegraph*, 1860, chap. xxi, p. 405.) An account of Steinheil's telegraph was read before the French Academy of Sciences, September 10, 1838. (*Comptes Rendus*, vol. vii, pp. 590–593.)

* Steinheil's paper "On Telegraphic Communication:" translated from the German, November 24, 1838, by Julian Guggsworth. Sturgeon's *Annals of Electricity*, etc. April, 1839, vol. iii, p. 512. A full description of Steinheil's telegraph is given in Dr. Julius Dub's *Anwendung des Elektromagnetismus*, Berlin, 1863; 2d edition, 1873, sect. v, pp. 339–347.

† These statements do not however do justice to Schilling's much earlier "simplified galvano-magnetic telegraph," with which Steinheil was very imperfectly acquainted.

magnetic bar—was given. All that we had to do therefore was to contrive that this motion should be made available for striking bells or for marking indelible dots. This falls within the province of mechanics, and there are therefore more ways than one of solving the problem. Hence the alterations that I have made in the telegraph of Gauss, and by which it has assumed its present form, may be said to be founded on my perception and improvement of its imperfections, in harmony with what I had previously laid down as necessary for perfect telegraphic communication. I by no means however look on the arrangement I have selected as complete; but as it answers the purpose I had in view, it may be well to abide by it till some simpler arrangement is contrived."* To Steinheil's lasting honor be it said, that when some dozen years later "a simpler arrangement" of the receiving instrument *was* brought to his attention, he was the first to appreciate it and to urge upon the Bavarian Government its adoption, to the abandonment of a portion of his own beautiful system. An example of magnanimity, or more properly of intellectual and unbiased judgment, much rarer with inventors of practical improvements in art, than with discoverers of truth in science.

These later developments of the telegraph, though in public use at the dates specified, not having been generally described by their authors immediately for publication, were from the meager notices of them found in the foreign journals, but little known in this country for several years afterward; and hence naturally arose the strong patriotic impression with many that the electro-magnetic telegraph was essentially an American invention.

About the same time that Steinheil in Munich was engaged in improving the needle telegraph, a distinguished chemical philosopher of London, was developing the galvanic battery; and he succeeded in giving that important apparatus a uniformity and continuity of action previously unhoped for. In the adopted forms of the Voltaic battery as arranged by Cruickshanks and others, the oxygen liberated by the active zinc surface rapidly attacked the plate, forming a coating of oxide over it which soon greatly impaired its chemical and galvanic efficiency. On the other hand, the hydrogen liberated at the surface of the copper, remained largely adherent to it in the form of minute bubbles, thus insulating it to a corresponding extent from contact with the liquid; while at the same time dissolved zinc was deposited on its exposed surface.

To obviate these impediments, Professor John Frederic Daniell provided a porous partition between the two metals, which while permitting the necessary conductibility from one side to the other, prevented the convective intermixture of the separated portions of liquid, and thus also allowed for the first time two different liquids to be employed for bathing the different metals. The liquid employed on the copper side

* Sturgeon's *Annals of Electricity*, etc. Mar. 1839, vol. iii, pp. 448, 449.

was a saturated solution of the sulphate of copper;—crystals of the sulphate being suspended in the liquid, for supplying the exhaustion of the copper. The liquid on the zinc side was a very diluted sulphuric acid. With this arrangement the oxygen evolved at the zinc surface forms mainly a zinc oxide, which dissolved by the liquid into a sulphate of zinc, is prevented from passing to the copper side of the partition, and the hydrogen evolved at the copper surface combining at once with the oxygen of the copper salt, forms water, and allows the free copper to be deposited on its own plates: and Professor Daniell was able to announce in a paper read before the Royal Society of London, February 11, 1836, "I have been led to the construction of a voltaic arrangement which furnishes a constant current of electricity for any length of time which may be required."*

Although it is true that the electric telegraph may be operated by the old form of battery—frequently renewed, (just as a good steam-engine may be efficiently worked by an inferior and wasteful boiler,) and also that a uniform current well adapted to the telegraph may be obtained from the magneto-electric machine, yet the "constant" battery has proved a most valuable boon in promoting the practical economy and success of modern telegraphy.

1837. Mr. William Fothergill Cooke and Prof. Charles Wheatstone obtained an English patent June 12, 1837, (No. 7390,) for a galvanometer or needle telegraph, very similar to the earlier one of Schilling, employing six wires and five indicating needles. At what date Prof. Wheatstone's attention was first directed to electrical signaling cannot now be ascertained; but in 1834 he had undertaken by means of his ingenious invention of the revolving mirror (capable of measuring the millionth of a second), to determine the velocity of ordinary electricity through half a mile of copper wire;† and a year or two later, through about four miles of the same. Early in 1836, he had contemplated a telegraph which with five needles, should give thirty signs. Mr. W. F. Cooke, attending a lecture on electro-magnetic communication by Professor Muncke, at Heidelberg, March 6, 1836, (as previously mentioned,) at which the telegraphic apparatus of Schilling was exhibited, at once "conceived the idea." In his "Statement of facts to the Arbitrators" in December, 1840, Mr. Cooke declares: "Mr. Möncke's experiment was at that time the only one upon the subject that I had seen or heard of. It showed that electric currents being conveyed by wires to a distance, could be there caused to

* *Phil. Trans. Roy. Soc.* 1836, vol. cxxvi, p. 107. In the "gravity battery" of Callaud, and of Varley, the porous diaphragm is dispensed with by placing the lighter liquid (a diluted solution of zinc sulphate) above the heavier liquid (a saturated solution of copper sulphate); the separation being maintained by their difference of specific gravity. In this arrangement the copper plate rests at the bottom of the cell, and the zinc plate is supported at its top.

† *Philosoph. Transac. of Roy. Soc.* (read June 19, 1834), vol. cxxiv, pp. 583–589. In this paper, Wheatstone says, that his first ineffectual attempt to discover a velocity of electricity was made in 1830. "The method by which I then proposed to effect this purpose, was announced in a lecture delivered by Dr. Faraday, at the Royal Institution, in June, 1830." (p. 583.)

deflect magnetic needles, and thereby to give signals. It was in a word a hint at the application of electricity to telegraphic purposes; but nothing more, for it provided no means of applying that power to practical uses. [!] . . . Within three weeks after the day on which I saw the experiment, I had made (partly at Heidelberg and partly at Frankfort) my first electric telegraph of the galvanometer form."* This apparatus comprised three indicating needles in connection with three circuits of six wires; each terminus of the line being provided with both transmitting keys, and indicating galvanometers. Mr. Cooke also applied a call-alarm, differing from Schilling's in having an ordinary clock-alarm, (similar to that used by Weber several years previously,) checked by an armature detent which was released on the excitement of an electro-magnet by the current. Not being skilled in electrical science however, nor aware of Henry's researches, he soon found the difficulty of operating with a "quantity" battery his galvanometer coils through a long circuit; and in February, 1837, he was introduced to Professor Wheatstone by Dr. P. M. Roget.† On comparing their respective projects of a needle telegraph, the two concluded to combine their exertions in a partnership; and in a little more than three months they secured a joint patent on their perfected system.‡ An experimental line between Euston Square and Camden Town Stations (a distance of a mile and a quarter), was worked with partial success July 25, 1837; and early in 1838, the patentees established a telegraph line between Paddington and West Dayton; the distance between these two points being about thirteen miles. Neither of these "co-inventors" appears at this time to have been aware of the early needle telegraph of Baron Schilling, whose arrangement had been so closely imitated by Mr. Cooke, and whose later simplification and improvement he had failed to reach.

As illustrative of the mistaken and inaccurate manner in which important accounts are often transmitted by even intelligent and honest men,—without due investigation and information, a quotation may here be made from the "Award" of arbitration between the subsequent conflicting claims of Cooke and of Wheatstone, rendered 27th April, 1841, by the referees, Marc Isambord Brunel, the eminent engineer, and John Frederick Daniell, the eminent chemist, meteorologist, and electrician. They state: "In March, 1836, Mr. Cooke, while engaged in scientific pursuits [!], witnessed for the first time one of those well-known experiments on electricity [!] considered as a possible means of communicating intelligence [!], which have been tried and exhibited from time to time [!] during many years by various philosophers!"§ And thus, in strange

* *The Electric Telegraph*, etc. by William Fothergill Cooke, 2 parts, 8vo. London, 1856, 1857; part ii, "Arbitration Papers," sects. 14, 18, pp. 14, 15.

† For an account of the circumstances attending and following this conference, see "Supplement," NOTE F.

‡ Messrs. Cooke & Wheatstone's English patent is dated June 12, 1837, No. 7390; and their American patent, June 10, 1840, No. 1622.

§ *The Electric Telegraph*, etc. by William Fothergill Cooke, 2 parts, 8vo., London, 1856, 1857; part i, p. 14: and part ii, p. 211; also p. 265.

exaggeration of Cooke's contribution to telegraphy, not only is Schilling's fine invention (of which the arbitrators had probably never heard) entirely overlooked, but even Professor Muncke's intelligent exposition of it, (by Mr. Cooke's representation—a "well-known experiment,") is dismissed as the recurrent exhibition "by various philosophers,"—probably as familiar in London as in Heidelberg.*

1837. About the date of the Cooke and Wheatstone patent (or a month or two later in the same year), a different form of electro-magnetic telegraph was being slowly developed in the city of New York. In the autumn of the year 1835, an American artist of acknowledged merit and of liberal education, a graduate of Yale College, about forty-five years of age, was appointed professor of the arts of design in the University of the city of New York, then recently established.† Occupying rooms in the unfinished building, he commenced experimenting on an electro-magnetic recording telegraph, the idea of which had for several years been floating in his mind. An upright square frame secured to the edge of a table, was provided with a transverse strip or shelf about midway of its height, on which was arranged a small Sturgeon electro-magnet lying upon its side, with its poles directed outward from the side of the frame. Directly in front of this, a wooden pendulum suspended from the top bar of the frame and having at its middle a small iron bar acting as an armature for the magnet, was allowed a small play to and from the lower part of the frame. To the lower end of the pendulum was attached a pencil projecting downward, and made adjustable so as to bear lightly against a strip of paper supported by a roller beneath, and slowly moved along near the edge of the table by clock-work, after the manner usually employed in recording apparatus. A single cup formed the galvanic element, and the circuit involving the electro-magnet was closed and opened by means of a lever armed with a wire fork which dipped into two mercury thimbles connected respectively

* Two other projects of needle telegraph on Ampère's and Schilling's plan, belonging to the latter part of 1837, require here only a passing notice. The first, that of a Mr. Alexander, exhibited at the Society of Arts in Edinburgh, comprised thirty transmitting keys with pins beneath, which on being depressed, closed the circuit by dipping into a transverse mercury trough, and thirty galvanometer needles at the receiving station, each carrying a light paper screen, which just covered a painted letter or mark when at rest, but which by deflection, exposed the desired letter to view. By ingeniously employing but a single wire for the return path of each circuit, the inventor required but thirty-one wires. (*Mechanics' Magazine*, London, Nov. 25, 1837, No. 746, vol. xxviii, pp. 122, 123.) The second scheme, very similar to the preceding, that of a Mr. Davy, exhibited at Exeter Hall, in London, employed but eight transmitting keys, each commanding three letters by different movements, and at the receiving desk twenty-four letters on ground glass, illuminated by a lamp, each of which became visible only on the removal of a screen on the needle, placed behind the glass. An observer remarked that in the desk "there is an aperture about 16 inches long and 3 or 4 inches wide, facing the eyes, perfectly dark. On this the signals appear as luminous letters, or combinations of letters, with a neatness and rapidity almost magical." (*Mech. Mag.* Feb. 3, 1838, No. 756, vol. xxviii, pp. 295, 296.)

†This is a different institution from the University of New York State, which has mainly a supervisory function.

with the two poles of the cup battery. A series of types having on their upper face teeth or cogs varying in number, were set up as desired in the groove of a rule or composing-stick, which was caused to pass under the free end of the circuit lever; and in this way the oscillation of the said lever over the projecting teeth determined the intervals of transmission of the magnetizing current according to the combinations previously arranged in the composing-stick. The movement of the strip of paper beneath the pencil of the pendulum produced a continuous straight line so long as the pendulum remained at rest; but at each momentary attraction of its armature by the magnet, (induced by the completion of the galvanic circuit on the passage of a tooth under the circuit lever,) the play of the pendulum caused a lateral deviation of its pencil, which thus produced a transverse V-shaped interruption of the straight line.

With this arrangement of apparatus the projector was enabled to produce signals through short circuits of wire: but he soon discovered to his dismay that on interposing more than a few yards of insulated wire, the oracle was dumb. Although the remedy for this defect (first discovered and demonstrated by Henry) had been for four or five years familiar to the students of science, the reading of the artist had not been in the direction of scientific literature; and he had conducted his experiments with a surprising indifference and inattention to the existing state of knowledge upon the subject. In this emergency he wisely procured the scientific assistance of a colleague, Dr. Leonard D. Gale, professor of chemistry in the same university, and the material and mechanical assistance of Mr. Alfred Vail, of the Speedwell Iron Works near Morristown, N. J.

The following is the account given by Dr. Gale of the early condition of this experimental telegraph, and of his own connection therewith: "In the winter of 1836–'37, Samuel F. B. Morse, who as well as myself was a professor in the New York University, city of New York, came to my lecture-room, and said he had a machine in his lecture-room or studio which he wished to show me. I accompanied him to his room, and there saw resting on a table a single-pair galvanic battery, an electro-magnet, an arrangement of pencil, a paper-covered roller, pinion-wheels, levers, &c., for making letters and figures to be used for sending and receiving words and sentences through long distances. . . . At this time as Morse assured me no man had seen the machine except his brother, Sidney E. Morse. . . . Morse's machine was complete in all its parts, and operated perfectly through a circuit of some forty feet, but there was not sufficient force to send messages to a distance. At this time I was a lecturer on chemistry, and from necessity was acquainted with all kinds of galvanic batteries; and knew that a battery of one or a few cups generates a large quantity of electricity, capable of producing heat, &c., but not of projecting electricity to a great distance; and that to accomplish this a battery of many cups is necessary. It was therefore evident to me that the one large cup-battery of Morse should be made into ten or fifteen smaller ones to make it a battery of intensity, so as to project the electric fluid. . . . Accordingly I substituted the battery of many cups for the battery of one cup. The remaining defect in the Morse machine, as first seen by me, was that the coil of wire around the poles of the electro-magnet consisted of but a few turns only, while, to give the greatest projectile power, the number of turns should be increased from tens to hundreds, as shown by Professor Henry, in his paper published in the *American Journal of Science*, 1831. . . . After substituting the battery of twenty cups for that of a single cup, we added some hundred or more turns to the coil of wire around the poles of the magnet, and sent a message through 200 feet of conductors; then through 1,000 feet; and then through ten miles of wire arranged on reels in my own lecture-room in the New York University, in the presence of friends. All these experiments were repeated with the original Morse machine, modified as I have stated, by increasing the number of battery-cups and the number of turns of wire around the magnet."*

The following account by the author himself, of his first experiments, is taken from his own deposition in the "Bain" case, in February, 1851: "In the year 1835, I was appointed a professor in the New York City University, and about the month of November of that year I occupied rooms in the university buildings. There I immediately commenced with very limited means to experiment upon my invention. My first instrument was made up of an old picture or canvas frame fastened to a table, the wheels of an old wooden clock moved by a weight to carry the paper forward, three wooden drums, upon one of which the paper was wound and passed over the other two, a wooden pendulum suspended to the top piece of the picture or stretching frame and vibrating across the paper as it passed over the center wooden drum, a pencil at the lower end of the pendulum in contact with the paper, an electro-magnet fastened to a shelf across the picture or stretching frame opposite to an armature made fast to the pendulum, a type-rule and type, for closing and breaking the circuit, resting on an endless band (composed of carpet-binding), which passed over two wooden rollers moved by a wooden crank and carried forward by points projecting from the bottom of the rule downward into the carpet-binding, a lever with a small weight on

* *Memorial of S. F. B. Morse*, 8vo. Washington, 1875, pp. 15–17. The practical improvements introduced by Professor Gale into the arrangement devised by Professor Morse appeared to the latter so obviously mere matters of degree that he felt confident (after they were shown) that he would himself have effected them by simple trial or experimentation; and he does not appear ever to have realized that any scientific principle was involved in the difference. But had he increased separately either the number of his galvanic elements or the number of coils upon his magnet, he would equally have failed to accomplish the desired result. The chance that he would have *combined* these increments may be estimated as very low indeed, when we consider that much wiser and more scientific heads had failed entirely to attain such purpose and arrangement.

the upper side and a tooth projecting downward at one end operated on by the type, and a metallic fork, also projecting downward over two mercury cups, and a short circuit of wire embracing the helices of the electro-magnet, connected with the positive and negative poles of the battery, and terminating in the mercury cups. . . . Early in 1836, I procured forty feet of wire, and, putting it in the circuit, I found that my battery of one cup was not sufficient to work my instrument.* . . . A practical mode of communicating the impulse of one circuit to another, such as that described in my patent of 1840, was matured as early as the spring of 1837, and exhibited then to Professor Gale, my confidential friend. Up to the autumn of 1837 my telegraphic apparatus existed in so rude a form that I felt reluctance to have it seen."†

In substantial accord with Professor Morse's deposition is that of his colleague and assistant, Professor Gale, taken in a previous case, and dated April 1, 1848, in which it is added that "On Saturday, the 2nd day of September, 1837, Professor Daubeny, of the English Oxford University, being on a visit to this country, was invited with a few friends to see the operation of the telegraph in its then rude form in the cabinet of the New York City University, where it then had been put up with a circuit of 1,700 feet of copper wire stretched back and forth in that long room. This exhibition of the telegraph, although of very rude and imperfectly constructed machinery, demonstrated to all present the practicability of the invention; and it resulted in enlisting the means, the skill, and the zeal of Mr. Alfred Vail."‡

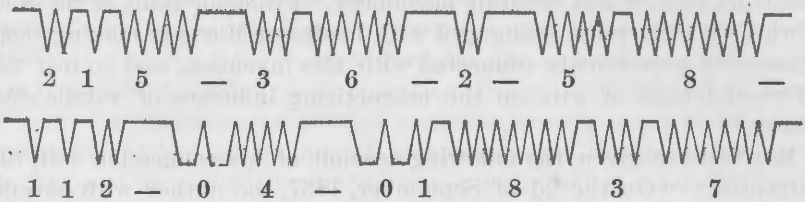
The record made on the trial exhibited September 2d, appears not to have been entirely satisfactory, for on the following Monday (September 4th) a still better performance was effected, as announced by a letter of that date addressed by Professor Morse to the editor of the New York "Journal of Commerce," in which the writer says: "I have the gratification of sending you a specimen of the writing of my telegraph, the actual transmission of a communication made this morning, in a more complete manner than on Saturday, and through the distance of one-third of a mile." This specimen of telegraphic communication, with its accompanying letter, was re-produced in the "Journal of Commerce" three days

* [Had Professor Morse tried 50 or 100 cups, he would have found them equally insufficient: a fact here quite ignored.]

† *Deposition of Samuel F. B. Morse:* Feb. 6, 7, and 8, 1851. In the case of "B. B. French and others *vs.* H. J. Rogers and others." Circuit court of U. S. for E. Dist. of Pa. April session 1850. No. 104. "Complainant's Evidence." Ninth answer, pp. 167–169.

‡ *Modern Telegraphy:* a pamphlet by Professor Morse, Paris, 1867, Appendix, p. 19. This first experimental exhibition, it must be remembered, was nearly three months after the date of Cooke and Wheatstone's patent, more than a month after their successful operation through a mile and a quarter, and while the English inventors were engaged in constructing a working line from Paddington to West Dayton. Mr. A. Vail, a young man of fine abilities, was a pupil of Dr. Gale's, and was by him introduced to Professor Morse.

later, and forms the earliest publication of the actual operation of the "Morse telegraph."* The dispatch is as follows:



This cipher is thus explained by the writer, reference being had to a dictionary suitably prepared with numbered words. "To illustrate by the diagram, the word 'successful' is first found in the dictionary, and its telegraphic number, '215,' is set up in a species of type prepared for the purpose; and so of the other words. The type then operate upon the machinery and serve to regulate the times and intervals of the passage of electricity. Each passage of the fluid causes a pencil at the extremity of the wire to mark the points as in the diagram. To read the marks, count the points at the bottom of each line. It will be perceived that two points come first, separated by a short interval from the next point. Set '2' beneath it. Then comes one point, likewise separated by a short interval. Set '1' beneath it. Then come five points. Set '5' beneath them. But the next interval in this case is a *long* interval; consequently the three numbers comprise the whole number '215.' So proceed with the rest until the numbers are all set down. Then by referring to the telegraphic dictionary, the words corresponding to the numbers are found, and the communication read. Thus it will be seen that by means of the changes upon ten characters, all words can be transmitted."†

In the above line or diagram representing the telegraphic dispatch, the symbol "Λ" (or inverted V), which occurs twice in the lower line, represents a cipher or zero; and this character, when preceding a figure or group of figures, indicates that the figure or group is to be read as an actual number, and not as the index of a word. Counting thus the number of V points in the above dispatch forming groups separated by a line (—), we obtain the following numbers: "215—36—2—58—112—04—01837." And this message when translated by help of the numbered dictionary will read "Successful experiment with telegraph September 4 1837."

An account of this success, published in Silliman's Journal for October, added the statement: "Since the 4th of September, one thousand feet more of wire No. 23 have been added, making in all two thousand

* Notwithstanding the very crude condition of this invention in September, 1837, as compared with that of Schilling in 1830 (or probably in 1823), and that of Gauss in 1833, the fact that intelligible signals were actually exhibited by it at this date, fully justifies the acceptance of this period as the time of its reduction to practical operation.

† New York *Journal of Commerce,* Thursday, September 7, 1837: (on the editorial page.)

seven hundred feet, more than half a mile of a reduced size of wire. The register still recorded accurately. Arrangements have been made for constructing new and accurate machinery. Professor Gale, of the New York City University, is engaged with Professor Morse in making some interesting experiments connected with this invention, and to test the effect of length of wire on the magnetizing influence of voltaic electricity."*

Mr. Vail has given the following account of his connection with the enterprise: "On the 2d of September, 1837, the author with several others witnessed the first exhibition of this electric telegraph, and soon after became a partner with the inventor. Immediate steps were taken for constructing an instrument for the purpose of exhibiting its powers before the members of Congress. This was done at the Speedwell Iron Works, Morristown, N. J. and exhibited in operation with a circuit of two miles. A few days after, it was again exhibited at the University of the City of New York, for several days, to a large number of invited ladies and gentlemen." †

About a month after this "successful experiment," (on the 6th of October, 1837,) Professor Morse filed in the United States Patent Office a "caveat," signed October 3, stating in the petition (dated five days earlier) "that the machinery for a full practical display of his new invention is not yet completed, and he therefore prays protection of his right till he shall have matured the machinery." The specification declares: "I have invented a new method of transmitting and recording intelligence by means of electro-magnetism: . . . for the purpose aforesaid, I have invented the following apparatus, namely: First, a system of signs by which numbers, and consequently words and sentences, are signified; second, a set of type adapted to regulate and communicate the signs, with cases for convenient keeping of the type, and rules in which to set up the type; third, an apparatus called a port-rule, for regulating the movement of the type-rules, which rules by means of the type in their turn regulate the times and intervals of the passage of electricity; fourth, a register which records the signs permanently; fifth, a dictionary or vocabulary of words numbered and adapted to this system of telegraph; sixth, modes of laying the conductors to preserve them from injury." These several parts are then more particularly described. "The signs are the representatives of numerals." The register comprises an electro-magnet actuating by its armature a lever or pendulum carrying a pencil or fountain pen, or small printing wheel, for marking on a strip or sheet of paper as already described. The modes of laying the conductors are by insulating the wires with silk or cotton wrapping, and coating with caoutchouc or other non-conductor, and also by inclosing them in iron, lead, or wooden tubes. The document concludes: "What I claim as my invention, and desire to secure by letters

*Silliman's *Am. Jour. Sci.* October, 1837, vol. xxxiii, p. 187.
†A. Vail's *Electro-Magnetic Telegraph*, 8vo. 1845, p. 154.

patent and to protect for one year by a caveat, is a method of recording permanently electrical signs which by means of metallic wires or other good conductors of electricity, convey intelligence between two or more places."

Of the above described apparatus, the two most important features were those numbered the first and the fourth,—the system of signs and the recording device; and though neither of these presented much originality, the method of the former being that long established for naval signals, and the clock-moved fillet of the latter being essentially the arrangement long employed for self-registering instruments generally, yet the *combination* of these parts with the others undoubtedly possessed great practical merit; and none the less that the several elements were evidently worked out independently by the inventor. It is not a little remarkable however, that of the specified six parts of this earliest invention of Professor Morse, *not one* enters into the established "Morse telegraph" of to-day. That feature regarded by the inventor as its vital and fundamental characteristic (the fourth), the subject of his formal "claim," survived the longest; but after undergoing considerable modification, it has for more than twenty years been neglected and abandoned.

In response to a public circular which had been issued by the Secretary of the Treasury, March 10, 1837, "with a view of obtaining information in regard to the propriety of establishing a system of telegraphs for the United States," Professor Morse addressed a communication to the honorable Secretary, dated September 27, 1837, pointing out the disadvantages of the old mechanical telegraphs as being "useless the greater part of the time:" (as in foggy weather and during the night.) He then proceeded: "Having invented an entirely new mode of telegraphic communication, which so far as experiments have yet been made with it, promises results of almost marvelous character, I beg leave to present to the department a brief account of its chief characteristics." After stating that at the time when he first conceived the thought (some five years previously) he had "planned a system of signs and an apparatus to carry it into effect," he added, "although the rest of the machinery was planned, yet from the pressure of unavoidable duties I was compelled to postpone my experiments, and was not able to test the whole plan until within a few weeks. The result has realized my most sanguine expectations."

The construction of a more complete apparatus was carried on at the Speedwell Iron Works of the Messrs. Vail, near Morristown, while Professor Gale pursued his experiments at the New York City University.*

Having finished his laborious task of numbering a dictionary, October 24, 1837, Professor Morse gave more attention to the Vail Works.†

* Professor Morse, writing to Mr. Alfred Vail, October 7, 1837, says: "Professor Gale's services will be invaluable to us, and I am glad that he is disposed to enter into the matter with zeal."

† "The dictionary is at last done. You cannot conceive how much labor there has been in it, but it is accomplished; and we can now talk or write anything by numbers." Professor Morse to A. Vail, October 24, 1837. (Prime's *Life of Morse*, chap. viii, p. 326.)

On his return from a visit to the works, he wrote back to Mr. Vail, on the 13th of November, 1837, "I arrived just in time to see the experiment Professor Gale was making with the entire ten miles, and you will be gratified and agreeably surprised when I inform you that the result now is that with a little addition of wire to the coils of the small magnet which I had all along used, the power was as great apparently through ten as through three miles. This result has surprised us all (yet there is no mistake), and I conceive settles the whole matter."

In a second communication to the Secretary of the Treasury, dated November 28, 1837, Professor Morse announced this encouraging success: "I informed you that I had succeeded in marking permanently and intelligibly at the distance of half a mile. Professor Gale of our university, and Mr. Alfred Vail, of the Speedwell Iron Works, near Morristown, N. J. are now associated with me in the scientific and mechanical parts of the invention.* We have procured several miles of wire, and I am happy to announce to you that our success has thus far been complete. At a distance of five miles, with a common Cruickshanks' battery of eighty-seven plates (four by three and a half inches, each plate), the marking was as perfect on the register as in the first instance of half a mile. We have recently added five miles more (making in all ten miles) with the same result; and we now have no doubt of its effecting a similar result at any distance."

On the completion of the new receiving and recording instruments at the Speedwell Iron Works, an experimental exhibition at the place, with three miles of coated copper wire, extended around a large factory-room, was made in the presence of a few friends, on the 6th of January, 1838; and on the 11th of January another exhibition was freely opened to the public. A report of the trial in a Morristown Journal explains how "the words were put up into numbers through the dictionary; the numbers were set up in the telegraph type in about the same time ordinarily occupied in setting up the same in a printing office; they were then all passed complete by the port-rule;" and being automatically recorded at the extreme end of the wire, "the marks or numbers were easily legible, and by means of the dictionary were resolved again into words."

Shortly after this, Professor Morse (or his assistant, Mr. Vail) devised for the first time a system of *alphabetic* symbols for his telegraph. It should not be forgotten that the vertical recording-lever of the original Morse appararatus was so arranged that it must necessarily mark a *continuous* line, either straight or zig-zag. It was never devised for an "alphabet," and was incapable of an intermittent dot or dash marking. The new instrument completed by Mr. Vail, and first operated on the

* In a letter to the Hon. Francis O. J. Smith, chairman of the Committee on Commerce, House of Representatives, dated February 15, 1838, Professor Morse writes: "It is proper that I should here state that the patent-right is now jointly owned in unequal shares by myself, Professor Gale, of New York City University, and Messrs. Alfred and George Vail." The patent was not actually issued till more than two years later.

6th of January, 1838, was differently organized, the recording-lever being for the first time arranged horizontally, and having an up and down movement, with an upright magnet under one end, and the moving fillet of paper above the other.*

On the 24th of January, 1838, an exhibition of the new apparatus and of its improved operation, was given at the New York City University, in the long room of the geological cabinet, through ten miles of wire; one of the five-mile reels being placed in the outgoing portion of the circuit, and the other five-mile reel on the returning line. On this occasion for the first time the words transmitted were entered, and recorded, in the new alphabet without the aid of the numbered dictionary.† The New York Journal of Commerce in noticing this performance remarked: "Professor Morse has recently improved on his mode of marking, by which he can dispense altogether with the telegraphic dictionary, using letters instead of numbers; and he can transmit ten words per minute, which is more than double the number which can be transmitted by means of the dictionary."‡

The instrument thus brought to a satisfactory working condition, was designed to be sent to Washington for exhibition to officers of the National Government, with a view of obtaining a grant from Congress for the construction of an actual line of telegraph between two cities. On the way from New York, the apparatus with its reels of wire was exhibited at Philadelphia, before a committee of the Franklin Institute (at its hall), on the 8th of February, 1838. The committee (whose chairman was Prof. Robert M. Patterson, then Director of the United States Mint at Philadelphia), after a careful examination, reported:

"The operation of the telegraph as exhibited to us was very satisfactory. The power given to the magnet at the register through a length of wire of ten miles, was abundantly sufficient for the movements required to mark the signals. The communication of this power was instantaneous." Referring then to the probable difficulties of efficient insulation, the committee proceeded: "Mr. Morse has proposed several plans; the last being to cover the wires with cotton thread, then varnish them thickly with gum-elastic, and inclose the whole in leaden tubes. More practical and economical means will probably be devised; but the fact is not to be concealed that any effectual plan must be very expensive.§ Doubts have been raised as to the distance to which the electri-

*On the question of the origin and invention of the "Morse-Alphabet," see "Supplement," NOTE G.

†The message sent through the wire on this occasion (Wednesday, January 24, 1838,) is spoken of as "the first *sentence* that was ever recorded by the telegraph." (Prime's *Life of Morse*, 8vo. N. Y. 1875, p. 331.) It was the first employment of the rectilinear dot and dash symbols.

‡New York *Journal of Commerce* of January 29, 1838.

§[It is to be remembered that Gauss and Weber, as also Steinheil, at this date had in actual and successful operation telegraph lines several miles in length, whose naked wires through the air were insulated only at their points of support. Although this important discovery of Weber had been in practical and public operation for about five years, no particular account of it seems to have been at that time published in this country.]

city of an ordinary battery can be made efficient; but your committee think that no serious difficulty is anticipated as to this point. The experiment with the wire wound in a coil may not indeed be deemed conclusive. . . . It may be proper to state that the idea of using electricity for telegraphic purposes has presented itself to several individuals, and that it may be difficult to settle among them the question of originality. The celebrated Gauss has a telegraph of this kind in actual operation, for communicating signals between the University of Göttingen and his magnetic observatory in its vicinity. . . . In conclusion, the committee beg leave to state their high gratification with the exhibition of Professor Morse's telegraph, and their hope that means may be given to him to subject it to the test of an actual experiment made between stations at a considerable distance from each other." *

About the middle of February, (1838,) Professor Morse arrived in Washington with his instrument and his reels of wire, and exhibited the operation of the telegraph to many dignitaries of the executive and legislative branches of government. A memorial was presented to Congress by the inventor, asking an appropriation to defray the expense of an experimental line between two cities; which being referred to the Committee on Commerce by the House of Representatives, was favorably reported by that committee April 6, through its chairman, Hon. Francis O. J. Smith. "The committee agree unanimously that it is worthy to engross the attention and means of the Federal Government to the full extent that may be necessary to put the invention to the most decisive test that can be desirable;" and in accordance with this opinion, "the committee recommend an appropriation of thirty thousand dollars, to be expended under the direction of the Secretary of the Treasury; and to this end submit herewith a bill." This bill however failed to receive the support of the majority, and a favorable action on this measure was not obtained for several years.

Meanwhile Professor Morse had been engaged with a killful attorney in preparing papers with a view to obtaining a patent. The specification (signed April 7, 1838) includes, in addition to the several parts described in the earlier caveat of October 3, 1837, the recently-devised system of alphabetic signs, a rotary port-rule for continuous action and a combination of circuits or electro-magnetic "relays." The invention is described as "an application of electro-magnetism in producing sounds and signs, or either, and also for recording permanently by the same means . . . any signs thus produced." "It consists of the following parts: First, a circuit of electric or galvanic conductors," etc. "Second, a system of signs by which numerals and words represented by numerals, and thereby sentences of words, as well as of numerals, and letters of any extent and combination of each, are communicated." "Third, a set of type adapted to regulate the communication of the above-mentioned signs." "Fourth, an apparatus called the port-rule [straight or

* *Journal of Franklin Institute,* February, 1838, vol. xxi, n. s. pp. 105–108.

circular] which regulates the movement of the type." "Fifth, a signal-lever which breaks and connects the circuit of conductors."* "Sixth, a register which records permanently the signs communicated." "Seventh, a dictionary, or vocabulary of words, to which are prefixed numerals." "Eighth, modes of laying the circuit of conductors."

After filing his application in the Patent Office, in order not to be forestalled in his intended efforts to obtain patents in Europe, by his own patent being sent and published abroad, Professor Morse filed a request that its issue might be suspended till his return.

Although the favorable report on the Morse memorial to Congress, made to the House of Representatives by its committee, failed to secure the appropriation recommended, Mr. Francis O. J. Smith, the chairman, was so well satisfied of the merits of the new telegraph, that on leaving Congress he at once became a partner in the enterprise, and accompanied Professor Morse in his departure for London, May 16, 1838.†

In consequence of the opposition of Wheatstone and Cooke, who had obtained an English patent June 12, 1837, Professor Morse's application for a patent in Great Britain was refused by the attorney-general, Sir John Campbell, July 12, 1838, (after the exaction of heavy fees,) on an unquestionable judicial quibble. The ostensible ground of rejection was clearly not warranted by the spirit or intent of the English patent law, as the *details* of the patent sought, had never been published either in this country or abroad.‡

The success of the American inventor in France was practically no greater; for although a nominal patent for that country was obtained on August 18, 1838, it was rendered nugatory by the ingenious legal

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*Although the "signal-lever" is here specially indicated, it differs widely in construction, arrangement, and operation, from the modern signal-lever or transmitting key; having only the function in common with it of a circuit-breaker. In his pamphlet, published at Paris in 1867, giving an account of his invention, Professor Morse says: "At the time of the construction of this first telegraphic instrument, I had not conceived the idea of the present *key manipulator* dependent on the skill of the operator, but I presumed that the accuracy of the imprinting of signs could only be secured by mechanical mathematical arrangements and by automatic process." (*Modern Telegraphy*, etc. p. 25.) In his argument presented to Sir John Campbell, the attorney-general of England, July 12, 1838, he urges as an evidence of characteristic novelty, "These types form such an essential part of my invention, that without them the practical utility and value of my invention is for the most part destroyed, and full one-half of the mechanism is disconnected from it, and is of no use in it." The Morse lever must not therefore be confounded with the existing finger-key. "The spring-lever key, as at present used in the Morse office, was suggested by Mr. Thomas C. Avery, of New York, but has received various modifications." (Turnbull's *Electro-Magnetic Telegraph*, 1852, pp. 49, 50.)

†"With this understanding a partnership was formed between Professor Morse, Professor Gale, Mr. Alfred Vail, and Hon. F. O. J. Smith, by the terms of which it was stipulated that Mr. Smith should go to Europe with Professor Morse, and secure patents for the telegraph in such countries as it should be practicable for him to do so." (Prime's *Life of Morse*, chap. viii, p. 344.)

‡Notwithstanding their illiberal interference with Morse's application in 1838, Messrs. William F. Cooke and Charles Wheatstone had the "self-possession" eighteen months later each to write a letter to Professor Morse, (dated January 17, 1840,) begging him to join them in their efforts to obtain an American patent! As a characteristic illustration of official contrast, Messrs. Cooke and Wheatstone (contrary to their expectations), on their own application, secured an American patent without opposition or obstruction June 10, 1840, ten days before the issue of Morse's patent, applied for more than two years earlier.

conditions, first, that to prevent forfeiture the patented invention must be carried into successful operation in France within two years; and secondly, that all private persons, companies, or corporations, were prohibited from putting a telegraph into operation in France. Disappointed in various promising expectations, and discouraged by repeated failures, Professor Morse returned to New York, April 15, 1839.

In May, 1839, he visited Princeton, for the purpose of seeing Professor Henry and obtaining from him the solution of certain doubts;—his colleague, Dr. Gale, being then absent on business. During this his first interview with Henry, occupying an afternoon and evening, he received from the full and frank expositions of his host every satisfaction he desired; and he had the great encouragement of hearing from the lips of that cautious investigator, that he foresaw no difficulty in magnetizing soft iron through a wire "at the distance of a hundred miles or more."*

The application filed by Professor Morse in the United States Patent Office, before he visited Europe, was allowed, and issued as a patent June 20, 1840. (No. 1647.) This patent comprised nine claims: 1, the combination of type, rule, lever, &c.; 2, the recording cylinder, &c.; 3, the types, signs, &c.; 4, the making and breaking of the circuit by mechanism, &c.; 5, the combination of successive circuits; 6, the application of electro-magnets to several levers, &c.; 7, the mode and process of recording by the use of electro-magnetism; 8, the combination and arrangement of electro-magnets in one or more circuits, with armatures for transmitting signs; and 9, the combination of the mechanism described, with a dictionary of numbered words.

The appropriation asked for from Congress, though earnestly pressed at successive sessions, failed to obtain the sanction of the House of Representatives; until after a wearisome delay of five years, a bill was finally carried through Congress, March 3, 1843, authorizing an expenditure of "the sum of thirty thousand dollars, . . . for testing the capacity and usefulness of the system of electro-magnetic telegraphs invented by Samuel F. B. Morse, of New York."

The stations selected for connection by the new telegraph were Washington and Baltimore, about forty miles apart. In order to form two complete circuits for this distance, one hundred and sixty miles of copper wire, covered with cotton, were ordered and delivered at New York City. Before inclosing the four lines in pipes, as contemplated, Professor Morse prudently determined to experiment on the magnetizing effect through this continuous length of insulated wire. The result of this experiment, which fully justified the expectation of Henry expressed to him four years before, is thus stated in a letter addressed to the Secretary of the Treasury, August 10, 1843:

* Prime's *Life of Morse*, chap. x, pp. 421, 422. Dr. Prime says of this visit, "A few days after receiving Professor Henry's kind invitation, Professor Morse went to Princeton, and passing the afternoon and evening with the great philosopher, returned the next morning to New York."

"The experiments alluded to were tried on Tuesday, and with perfect success. I had prepared a galvanic battery of three hundred pairs, in order to have ample power at command; but to my great gratification, I found that one hundred pairs were sufficient to produce all the effects I desired through the whole distance of one hundred and sixty miles. It may be well to observe that the hundred and sixty miles of wire are to be divided into four lengths of forty miles each, forming a fourfold cord from Washington to Baltimore. Two wires form a circuit; the electricity therefore in producing its effects at Washington from Baltimore, passes from Baltimore to Washington and back again to Baltimore, of course travelling eighty miles to produce its result. One hundred and sixty miles therefore gives me an actual distance of eighty miles; double the distance from Washington to Baltimore. The result then of my experiments on Tuesday, is that a battery of only a hundred pairs at Washington, will operate a telegraph on my plan eighty miles distant with certainty, and without requiring any intermediate station."

As it was part of the original plan (as set forth in the caveat of 1837) to lay the conducting wires underground, Professor Morse, in 1843, devised a method of forming a lead pipe around the group of prepared and insulated wires, that is of introducing the compound cord into the pipe in the process of its construction. He obtained a patent for this project October 25, 1843, (No. 3316,) claiming "the method of introducing wires into hollow pipes whilst making the same, by introducing the wires through a hollow mandrel on which the pipe is made." This process was practically carried out, though with the extreme risk of constantly impairing the insulation of the wires by the operation.

Professor Gale has given the following account of the method of laying the telegraph line and of the result. "A plow was used, with a share running two and a half feet deep, and carrying a coil of insulated wire inclosed in a coil of lead pipe which the plow deposited in the ground and covered as the plow progressed. Forty miles of lead pipe were made in New York in the autumn of 1843, and shipped to Baltimore in the end of November. Up to this date I had been engaged in New York inspecting the manufacture of the lead pipe and charging the same with the insulated wire fed into the pipe by machinery while the pipe was drawn. I reached Baltimore in the early part of December, and learned that the party had nearly reached the Relay House. Nine miles had been laid; on inspection of which, not one mile of wire was found to be sufficiently insulated to carry the electric current from end to end of the reach."*

The plan was finally abandoned early in 1844, after more than half of

* *Morse Memorial*, Washington, 1875, pp. 18, 19. Steinheil, in 1837, remarked: "Numerous trials to insulate wires and to conduct them below the surface of the ground have led me to the conviction that such attempts can never answer at great distances, inasmuch as our most perfect insulators are at best but very bad conductors. And since in a wire of very great length the surface in contact with the so-called insulator is uncommonly large when compared with the section of the metallic conductor, there necessarily arises a gradual diminution of force." (Sturgeon's *Annals of Electricity*, etc. April, 1839, vol. iii, p. 510.)

the appropriation had been expended.* In March, 1844, it was decided to put the wires on poles, after the manner successfully adopted by Weber at Göttingen eleven years before. The different plans of insulating support proposed, were submitted by Professor Morse to Henry for his opinion, and he decided in favor of Mr. Ezra Cornell's plan of separating the wires as far apart as convenient, and attaching each wire to an independent glass insulator.† The line was accordingly erected on this plan; and by the middle or latter part of May, 1844, was completed from Washington to Baltimore. On the 24th of that month, the first formal message was transmitted through it between the two cities, and recorded by the electro-magnet in the dot-and-dash alphabet.‡ From this time the success of the electric telegraph in the United States was assured, and its extension over our broad domain was comparatively rapid.

This prolonged review of the history of the "Morse telegraph" has been ventured upon in this connection, partly to bring out into just relation and relief one or two important points, and in part to illustrate the gradual progress of development of the system, in the career of a single inventor. With that strong "subjectivity" (perhaps essential to the success both of the artist and of the artisan) which characterized him, Professor Morse always believed his invention to have been practically full-fledged at its birth, or rather at its conception; and quite unconscious of the slow and small advances derived from gathered experience or external suggestion, failed seemingly to realize how completely his earlier methods were discarded and displaced by later improvements.§

* Professor Morse says: "It was abandoned, among other reasons, in consequence of ascertaining that in the process of inserting the wire into the leaden tubes (which was at the moment of forming the tube from the lead at melting heat) the insulated covering of the wires had become charred at various and numerous points of the line to such an extent that greater delay and expense would be necessary to repair the damage than to put the wire on posts." (Prime's *Life of Morse*, chap. xi, p. 478.)

† Mr. Cornell afterward distinguished himself by devoting, in 1865, half a million of dollars from the profits of his telegraphic enterprises, to the founding at Ithaca, N. Y. of the university bearing his name. He subsequently contributed nearly as much more; making his total endowment in the neighborhood of a million dollars.

‡ The completion of the experimental telegraph authorized by act of Congress was thus formally announced by Professor Morse to the Secretary of the Treasury, under whose direction the appropriation had been placed: "Washington, June 3, 1844. SIR: I have the honor to report that the experimental essay authorized by the act of Congress on March 3, 1843, appropriating 30,000 dollars for testing my system of electro-magnetic telegraph, 'and of such length and between such points as shall test its practicability and utility,' has been made between Washington and Baltimore, a distance of forty miles, connecting the Capitol in the former city with the railroad depot in Pratt street in the latter city. . . ." This was six years after the English line of thirteen miles had been in operation. While Lomond, in 1787, and Steinheil, in 1837, had employed but a single wire for transmitting messages from either end, Morse, in 1844, required two circuits of four wires for the same performance; one pair of wires for the outward and one pair for the inward passage.

§ In a letter addressed to Donald Mann, esq., December, 1852, Professor Morse rather quaintly remarks: "In elaborating the invention in its earlier stages, many modifications of its various parts were tried, and many of the supposed improvements then deemed necessary to its perfection have since been found unnecessary and useless." (*American Telegraph Magazine*, December 15, 1852, vol. i, No. 3, p. 130.)

Morse's "first conception."—After a three years' sojourn in Europe, from 1829 to 1832, spent principally in Italy, devoted exclusively to the study and pursuit of his art as painter, Mr. Morse on his homeward voyage from France in the ship Sully, formed the acquaintance of Dr. Charles T. Jackson, of Boston, a fellow-passenger. He first "conceived the idea" of an electric telegraph on the 19th of October, 1832, from a conversation with Dr. Jackson on the subject; and the suggestion impressed him with the surprise of a truly new conception. His first thought appears to have been the application of electricity or galvanism to a chemically recording telegraph; and this project, laid aside for that of the electro-magnet, was afterward revived and cherished, till in 1849, he procured a patent for it, as already stated.

Professor Morse in his letter to Dr. C. T. Jackson, dated September 18, 1837, controverting the claim of the latter to a share in the invention of the electric telegraph, says: "I lose no time in endeavoring to disabuse your mind of an error into which it has fallen in regard to the electro-magnetic telegraph. You speak of it as 'our electric telegraph,' and as a 'mutual discovery.' . . . I have a distinct recollection of the manner, the place, and the moment, when the thought of making an electric wire the means of communicating intelligence, first came into my mind. . . . We were conversing on the recent scientific discoveries in electro-magnetism; . . . I then remarked, this being so, if the presence of electricity can be made visible in any desired part of the circuit, I see no reason why intelligence might not be transmitted instantaneously by electricity. You gave your assent that it was possible. . . . I asked you if there was not some mode of decomposition which could be turned to account. You suggested the following experiment, which we agreed should be tried together, if we could meet for that purpose. It was this: to decompose by electricity glauber salts upon the paper which was first to be colored with turmeric." The writer then argues that this plan not having been jointly tried, and an entirely different device (the electro-magnet) having been adopted by himself, there was no joint invention.*

In his letter to Dr. C. T. Jackson, dated December 7, 1837, Professor Morse says: "I consulted you to ascertain if there were not some substance easily decomposed by the simple contact of a wire in an electric state. It was then, and not till then, that you suggested turmeric paper dipped in a solution of sulphate of soda. . . . I do not charge you with intentional neglect; I readily allow your excuses for not trying the experiments; but these excuses do not alter the fact that your neglect retarded my invention, and compelled me after five years' delay, to consider the result of that experiment as a failure, and consequently to de-

* Amos Kendall's *Full Exposure of Dr. Charles T. Jackson's Pretensions*, etc. First edition, N. Y. 1850. Second edition, printed in Paris, 1867: pp. 64, 65. Neither Professor Morse nor Dr. Jackson was aware that the project had been suggested seventeen years before, by Dr. J. R. Coxe, of Philadelphia; and that it had been successfully tried four or five years before, by Mr. H. G. Dyar, of New York.

vise another mode of applying my apparatus,—a mode entirely original with me."*

In a letter to Mr. Alfred Vail, not long after having formed a partnership with that gentleman, he wrote: "I claim to be the original suggester and inventor of the electric magnetic telegraph, on the 19th of October, 1832, on board the packet-ship Sully, on my voyage from France to the United States, and consequently the inventor of the first really practicable telegraph on the electric principle."† Some ten years later he wrote to Professor Walker: "It is at the date, 1832, of Baron Schilling's invention of his needle-telegraph (since abandoned as impracticable from various and obvious causes), that I conceived my electro-magnetic telegraph, and first devised an apparatus applying magnetism produced by electricity or the power of the electro-magnet to imprint characters at a distance."‡ And such was ever his firm conviction. Some twenty years later, he wrote at Paris: "If it be asked why I have assumed the date of the year 1832 as a standpoint, I reply, because at that date the idea was first conceived, and the process and means first developed."§

The invention however as unfolded in his caveat of October 3, 1837, is sufficiently embryonic for physiological study; and though our patent law, on grounds of sound policy, excludes all evidence of the inception of a foreign competitive invention, admitting only perfected and fully published details successfully to interfere (in a question of priority) with the first suggestions of the American inventor,|| obviously no such patriotic rule is admissible in any scientific history of the progress of actual discovery. Interesting as the earliest gleams of a successful application and invention undoubtedly are, they are too little accessible to impartial investigation to claim the prerogative of a recognized chronology.

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* This letter seems very positively to exclude the claim to having "conceived the idea" of the *magnetic* telegraph in 1832.

† Vail's *Electro-Mognetic Telegraph*, 1845, p. 154.

‡ Morse's letter to Professor Sears C. Walker, dated Washington, January 31, 1848. The writer is excusable for assuming 1832 as the date of Baron Schilling's invention, (the date of his return from China,) as this is the date usually assigned in the popular text-books. Schilling's invention however so far from being either "impracticable" or "abandoned," is the essential basis of the telegraph now in use throughout England.

§ *Modern Telegraphy*, a pamphlet by S. F. B. Morse. Paris, 1867, p. 10. In a letter to Donald Mann, esq. (editor of the Telegraph Magazine), dated "Poughkeepsie, December, 1852," Professor Morse stoutly maintained his claim to priority of practical development (if not of first conception) of an electric recording telegraph; and with paternal exaggeration he declared, of his first crude experiment at the close of the year 1835, "The truth is, the child was born, and breathed, and spoke, in 1835. It had then all the essential characteristics of the future man." (*American Telegraph Magazine.* December 15, 1852, vol. i, No. 3, p. 130.) Its first transmission of an intelligible message was made September 2, 1837.

|| "Whenever it appears that a patentee at the time of making his application for the patent believed himself to be the original and first inventor or discoverer of the thing patented, the same shall not be held to be void on account of the invention or discovery, or any part thereof, having been known or used in a foreign country before his invention or discovery thereof, if it had not been patented or described in a printed publication." (*Act of July* 4, 1836, section 15, *Revised Statutes*, approved March 2, 1877, title lx, sec. 4923.)

Whether judged by the standard of original conception, of practical operation, or of actual introduction into use, the Morse telegraph must be assigned a position tolerably low down in the list.* More than sixteen years before Professor Morse's first conception of the idea, Dr. J. R. Coxe, professor of chemistry in the University of Pennsylvania, at the beginning of 1816, "conceived the idea" of a practical electro-chemical telegraph, whose signals should be permanently *recorded* by the decomposition of metallic salts;† the precursor of Dyar's electro-chemical telegraph, successfully operated in 1828, (about five years before Morse's first conception,)—of Bain's electro-chemical telegraph, (patented December 12, 1846,)—and of Morse's electro-chemical telegraph, (patented May 1, 1849,) a third of a century afterward. Schilling's electro-magnetic telegraph developed to a "practical operation" in 1823, certainly before 1825, preceded that of Morse more than a dozen years. And the electro-magnetic telegraph of Gauss and Weber (certainly "conceived" before 1832) was in actual use and employment more than ten years before the similar establishment by Professor Morse; while that of Steinheil, probably conceived as early, was some eight years earlier than his in its practical introduction into use.‡

That Professor Morse would greatly have expedited his own improvements, and have saved himself a large amount of wasted time and labor, if he had studied more carefully the state of the art at the commencement of his experiments in 1835, is sufficiently obvious. But his complete unconsciousness—not only of the earlier successes of others in developing the galvanic telegraph, but of even the elementary facts of scientific history bearing on the problem, as well at the time of his original "conception" on board the ship Sully from the fecundating suggestion of Dr. Jackson, as during the years following, in which the invention was being slowly matured,—would be incredible on any other testimony than his own. In his first letter to the Secretary of the Treasury, dated September 27, 1837, he announced "having invented an entirely new mode of telegraphic communication." In a letter to Mr. A. Vail, some time afterward, he wrote: "I ought perhaps to say that the conception of the idea of an electric telegraph was original with me at that time, and I supposed that I was the first that had ever associated the two words together, nor was it until my invention was completed and had been successfully operated through ten miles, that I for the first time

* Nearly two years before Professor Morse had met with Dr. C. T. Jackson, Henry had "conceived" and executed an experimental electro-magnetic telegraph, of a mile circuit.

† Thomson's *Annals of Philosophy*, February, 1816, vol. vii, p. 163.

‡ In a letter to his daughter dated July 26, 1838, (written from Havre, just on his arrival in France from London,) Professor Morse says somewhat curiously of the telegraph of Wheatstone, "he has invented his I believe without knowing that I was engaged in an invention to produce a similar result; for although he dates back to 1832, yet as no publication of our thoughts was made by either, we are evidently independent of each other." (Prime's *Life of Morse*, chap. ix, p. 358.) The popular infatuation in England as to the originality and priority of the Cooke and Wheatstone telegraph is probably quite equal to that prevalent in America as to the superior claims of the Morse telegraph. Wheatstone's *scientific* distinction or his title to enduring fame, fortunately does not repose on his telegraph.

learned that the idea of an electric telegraph had been conceived by another." *

Some time earlier than this, or five years after their conversations on ship-board, Professor Morse wrote to Dr. Jackson, (in a letter dated August 27, 1837, seeking his indorsement of the writer's originality in electrical telegraphy,) and avowed: "I claim for myself, and consequently for America, priority over all other countries in the invention of a mode of communicating intelligence by electricity!" In a second letter to the same person, dated New York City University, September 18, 1837, acknowledging his correspondent's original introductory remarks on electricity and electro-magnetism during their homeward voyage, but differing from him as to some of the consequent circumstances, he affirmed: "I then remarked, this being so, if the presence of electricity can be made visible in any desired part of the circuit, I see no reason why intelligence might not be transmitted instantaneously by electricity!" And in the same letter he contended, "The *discovery* is the original suggestion of conveying intelligence by electricity.† The *invention* is devising the mode of conveying it. The discovery, so far as we alone are concerned, belongs to me: and if by an experiment which we proposed to try together we had mutually fixed upon a successful mode of conveying intelligence, then we might with some propriety be termed mutual or joint inventors. But as we have never tried any experiment together, nor has the one proposed to be tried by you, been adopted by me, I cannot see how we can be called mutual inventors. You are aware perhaps that the mode I have carried into effect after many and various experiments with the assistance of my colleague, Professor Gale, was never mentioned either by you or to you.‡ . . . I have always said in giving any account of my telegraph, that it was on board the ship during a scientific conversation with you that I first conceived the thought of an electric telegraph. I have acknowledgments of similar kinds to make to Professor Silliman and Professor Gale, . . . and to the latter I am most of all indebted for substantial and effective aid in many of my experiments. If any one has a claim to be mutual inventor on the score of aid by hints, it is Professor Gale; but he prefers no claim of the kind."§ In his third letter, dated New York City

* Vail's *Electro-Magnetic Telegraph*, p. 154.

† Professor Morse's conception of "discovery" does not appear to have been very profound.

‡ [Another explicit statement that he did not "conceive the idea" of the *magnetic* telegraph in 1832, or on board the ship Sully.]

§ Dr. Jackson in his reply, dated Boston, November 7, 1837, said: "This claim of yours is to me a matter of surprise and regret. . . . You will not I presume venture to maintain that you at that time knew anything about electro-magnetism more than what you learned from me. . . . I am certainly desirous of doing you justice to the fullest extent, and have always spoken of your merits as I hope I shall always have occasion to do. . . . Honor to whom honor is due shall be my motto, and I must I believe fail in this duty if I should say that the first idea of an electro-magnetic telegraph was conceived by an American citizen. . . . The 'discovery' is not then to be claimed by us. I have invented a new instrument; so perhaps you have, for I do not yet know what your new one is, since you say I have not seen it nor heard about it beyond your announcement."

University, December 7, 1837, Professor Morse reiterated: "Your memory and mine are at variance in regard to the first suggestion of conveying intelligence by electricity. I claim to be the one who made it, and in the way which I stated in my letter to you. . . . The idea that I had made a brilliant discovery, that it was original in my mind, was the exciting cause and the perpetual stimulus to urge me forward in maturing it to a result. Had I supposed at that time, that the thought had ever occurred to any other person, I would never have pursued it; and it was not till I had completed my present invention, that I was aware that the thought of conveying intelligence by electricity had occurred to scientific men some years before. . . . The single scientific fact ascertained by Franklin, that electricity can be made to travel any distance instantaneously, is all that I needed to know, aside from mathematical and mechanical science, in order to plan all I invented on board the ship."*

These extracts sufficiently show the distinguished inventor's profound incomprehension, as well of the nature of the problem to be solved, as of the scientific principles involved in surmounting his fundamental difficulties. That his colleague, Professor Gale, should by the mere application of existing knowledge and established fact, make his magnetic signals operative through successively increasing lengths of wire until ten miles were included in the circuit, appeared—if remarkable, at least quite natural. That any special credit should be due to any one but himself and his invention, in the accomplishment of such a result, appeared no less unnatural and irrational: and Dr. Gale has recorded "Professor Morse's great surprise" when his attention was first called to Henry's paper in Silliman's Journal of January, 1831, a year or two after his magnet and battery had been so modified in accordance therewith as to correlate them in "intensity." That even then the inventor understood the real import of the paper is rendered doubtful by subsequent developments: his surprise being apparently excited mainly by Henry's suggestion that his researches were "directly applicable to the project of forming an electro-magnetic telegraph."

Prof. Sears C. Walker, the eminent astronomer, in a deposition taken in a telegraph suit of "French *vs.* Rogers," has thus recorded his recollection of an interesting interview between Professors Henry, Morse, and Gale, in January, 1848, at which he was present: "The result of the interview was conclusive to my mind that Professor Henry was the sole discoverer of the law on which the 'intensity' magnet depends for its power of sending the galvanic current through a long circuit. I was also led to conclude that Mr. Morse in the course of his own researches and experiments, before he read Professor Henry's article before alluded to, had encountered the same difficulty Mr. Barlow and those who preceded him had encountered; that is the impossibility of forcing the galvanic

* *Full Exposure of Dr. Charles T. Jackson's Pretensions*, etc. By Amos Kendall. 1st ed. 1850; 2d ed. printed in Paris, 1857: pp. 61–74.

current through a long telegraph line. His own personal researches had not overcome this obstacle. I also learned at the same time, by the conversations above stated, that he only overcame this obstacle by constructing a magnet on the principle invented by Professor Henry, and described in his article in Silliman's Journal. His attention was directed to it by Dr. Gale."*

In consequence of this friendly interview, Professor Morse, with a frankness creditable to the natural impulses of his character, a short time afterward addressed a letter to Professor Walker, from which the following extracts are made:

"WASHINGTON, January 31, 1848.

"DEAR SIR: I have perused with much interest that part of your manuscript entitled 'Theory of Morse's Electro-Magnetic Telegraph,' which you were so kind as to submit to my examination. The allusion you make to 'the helix of a soft-iron magnet prepared after the manner first pointed out by Professor Henry,' gives me an opportunity of which I gladly avail myself, to say that I think justice has not hitherto been done to Professor Henry, either in Europe or this country, for the discovery of a scientific fact which in its bearing on telegraphs, whether of the magnetic needle or electro-magnet order, is of the greatest importance. . . . Thus was opened the way for fresh efforts in devising a practicable electric telegraph; and Baron Schilling, in 1832, and Professors Gauss and Weber, in 1833, had ample opportunity to learn of Henry's discovery, and avail themselves of it, before they constructed their needle telegraphs.† . . . To Professor Henry is unquestionably due the honor of the discovery of a fact in science which proves the practicability of exciting magnetism through a long coil or at a distance, either to deflect a needle or magnetize soft iron. . . .

"With great respect, your obedient servant,

"SAMUEL F. B. MORSE."

This just and honorable recognition was well calculated to reflect an added luster, in the minds of the intelligent, upon Professor Morse's unquestionable achievements. But the writer a few years later, perhaps embittered by the sweeping constructions placed by hostile advocates upon the enforced statements of Henry (exacted in strongly-contested litigations between rival telegraph inventors or their sustaining companies), was unfortunately led in evil hour by flattering partisans to undo this gracious work.

In a pamphlet essay dated Locust Grove, New York, December, 1853, and published in January, 1855, Professor Morse hazarded the intrepid

* *The case of French* vs. *Rogers.* Respondent's evidence, p. 199. Quoted by President Felton: *Smithsonian Report* for 1857, pp. 94, 95. The attention of Professor Morse was in reality not called to Henry's discovery by Dr. Gale, till a considerable time after it had been successfully applied to the experimental circuits of the infant telegraph.

†[Schilling's telegraphic experiments (involving no great length of circuit) were earlier than Henry's discoveries; and the expedient of so delicate an indicator as the reflecting galvanometer employed by Gauss and Weber seems to show that they had not adapted fully the electric current to the "intensity" coil, as recommended by Henry.]

statement: "First. I certainly shall show that I have not only manifested every disposition to give due credit to Professor Henry, but under the hasty impression that he deserved credit for discoveries in science bearing upon the telegraph, I did actually give him a degree of credit not only beyond what he had received at that time from the scientific world, but a degree of credit to which subsequent research has proved him not to be entitled. Secondly. I shall show that I am not indebted to him for any discovery in science bearing on the telegraph; and that all discoveries of principles having this bearing were made, not by Professor Henry, but by others, and prior to any experiments of Professor Henry in the science of electro-magnetism."*

In the inevitable dilemma thus assumed by the pamphleteer, under the clear light of historic record, it is most charitable not to impugn the writer's *candor*. The evidences diligently gathered by him, of electric impulse transmitted to great distances, before the date of Henry's investigations, certainly *seem* to show a surprising misconception of the phenomena and the principles of electro-magnetism. That with such misconception he should fail to appreciate an indebtedness to Henry's labors, is perhaps not surprising; but that he should thus ignore the services and statements of his faithful friend and colleague—Professor Gale, his great obligations to whom had been constantly admitted, appears less amenable to explanation or excuse.

Professor Morse could say with undoubted truth, that not till after the successful working of his invention, had he ever heard of Henry's researches. In his letter to Professor Walker, just above quoted, in referring to the time and the nature of his invention, he wrote: "I was utterly ignorant that the idea of an electric telegraph of any kind whatever, had been conceived by any other person. I took it for granted that the effects I desired could be produced at a distance; and accordingly in the confidence of this persuasion, I devised and constructed my apparatus for the purpose. I had never even heard or read of Professor Henry's experiments, nor did I become acquainted with them until after all my apparatus was constructed and in operation through half a mile of wire, at the New York City University, in 1837. I then learned for the first time that an electric telegraph of some kind had been thought of before I had thought of it." In his pamphlet of January, 1855, he mentions that at the date of Henry's publication in Silliman's Journal, he was sojourning in Italy. "From the autumn of the year 1829 till the autumn of the year 1832 I was in Europe, principally in Italy. . . . The fact is, it did not come to my knowledge until five years after my return, in 1837."†

* *A Defence against the injurious deductions drawn from the deposition of Prof. Joseph Henry* [in the several telegraph suits]; by Samuel F. B. Morse, January 1855, p. 8. (See "Supplement," NOTE H.)

†Morse's *Defence against the injurious deductions*, etc. (p. 15, and foot-note). Thus while Morse—dreaming only of artistic fame, was assiduously cultivating his art in Italy, nearly two years before he met with Dr. Jackson on the homeward ship, or before the conception of electric signaling had dawned upon his mind, Henry had an electro-magnetic circuit of a mile, with bell signal, in actual operation at the Albany Academy.

Professor Gale, when asked in 1856, if he would give a statement for publication, of the Morse apparatus as originally constructed, and before being modified by himself, promptly responded in a letter dated Washington, April 7, 1856: "This apparatus was Morse's original instrument, usually known as the type apparatus, in which the types, set up in a composing-stick, were run through a circuit-breaker, and in which the battery was the cylinder battery, with a single pair of plates. The sparseness of the wires in the magnet coils, and the use of the single cup battery, were to me on the first look at the instrument, obvious marks of defect, and I accordingly suggested to the professor, without giving my reasons for so doing, that a battery of many pairs should be substituted for that of a single pair, and that the coil on each arm of the magnet should be increased to many hundred turns each: which experiment (if I remember aright) was made on the same day, with a battery and wire on hand, furnished I believe by myself: and it was found that while the original arrangement would only send the electric current through a few feet of wire, (say from fifteen to forty,) the modified arrangement would send it through as many hundred. Although I gave no reasons at the time to Professor Morse for the suggestions I had proposed in modifying the arrangement of the machine, I did so afterward; and referred in my explanations to the paper of Professor Henry, in the nineteenth volume of the *American Journal of Science*. . . . At the time I gave the suggestions above named, Professor Morse was not familiar with the then existing state of the science of electro-magnetism. Had he been so, or had he read and appreciated the paper of Henry, the suggestions made by me would naturally have occurred to his mind, as they did to my own. . . . Professor Morse expressed great surprise at the contents of the paper when I showed it to him, but especially at the remarks on Dr. Barlow's results respecting telegraphing."*

In a letter published in the Sunday Chronicle at Washington, in 1872, Professor Gale (strongly vindicating the propriety of erecting a monument to Professor Morse—not as a Discoverer but as an Inventor,) conceded that "Morse knew nothing of Henry's discovery when he invented his machine. Henry's discovery was published in 1831. Five or six years later Morse invented his telegraphic machine, without having seen an account of Henry's experiments till shown to him by myself."† And from this consideration he justly exonerates him from the imputation of plagiarism which had been inconsiderately brought against the distinguished inventor. In a letter addressed to Prof. E. N. Horsford, of Cambridge, Mass., dated Washington, May 18, 1872, the same writer said: "I adapted to Morse's machine the modification which was taken from Henry's experiments of 1831. [Properly of 1829, and 1830.] But Morse, not having been accustomed to investigate scientific facts, could not appreciate the investigations of Henry as applicable to the tele-

Smithsonian Report for 1857, pp. 92, 93.

†*Sunday Chronicle*, Washington, March 3, 1872.

graph; and I presume that Morse never did fully appreciate the benefit which his machine derived from Henry's discovery."*

Professor Morse's real merit (and his real contribution to telegraphy) consists, first, in the adaptation of the armature of a Henry electro-magnet to the purpose of a recording instrument, and secondly, in connection therewith, the improvement on the Gauss and Steinheil dual-sign alphabets, (made either by himself, or his assistant, Mr. Vail,) of employing, instead of alternating or vibratory markings, the simple "dot-and-dash" alphabet in a single line. Whatever may have been the indebtedness of Professor Morse to Dr. Jackson for the suggestion of the first idea of an "electric" telegraph, it is quite clear from the incoherent claims of Dr. Jackson himself, that these two really important improvements were original with Morse, and were in no sense derived from Jackson.†

Claims so moderate, though so meritorious, (as might be supposed) would scarcely satisfy the ambition of the patentee and his supporters, conscious of the equally meritorious exertion and enterprise by which through tedious ordeals of obstruction and difficulty a great practical success had been achieved, and before whom—in just reward—prophetic visions of a grand commercial monopoly loomed in large perspective. And thus by ignoring and undervaluing the results accomplished by those earlier in the field, the owners of the patent exerted themselves to repress competing systems, and to arrogate entire invention and proprietorship of the electro-magnetic telegraph.

To the vast majority—suddenly dazzled by so magnificent a culmination of invention, such claims appeared entirely legitimate; to the studious few—prepared to discriminate, they appeared as entirely inadmissible. The judicial tribunals—disposed to sustain a vested right with largest and most liberal interpretation, yet pronounced in final appeal such claims untenable and overstated.‡

To so eminent a pioneer in telegraphy as Henry, perhaps more than to any other, must the overweening pretensions of the "Morse Telegraph" have been obvious and untenable; and yet with that impartiality of judgment—that rare independency of personal bias which so marvelously distinguished him, he never permitted himself to underestimate Morse's true merits, nor did he abstain from defending them with a heartiness probably greater than was accorded by any of his scientific compeers. For Professor Morse personally he felt a sympathetic regard; which continued uninterrupted and unabated till the unfortunate epoch when he was so ungratefully assailed and so wantonly traduced.§

* *Memorial of Samuel F. B. Morse.* (Meeting in Faneuil Hall.) Boston, 1872, p. 37.

† These two features so impressed the candid Steinheil, the foremost of telegraphers, as to lead him at once to accept them as great improvements on his own ingenious method of recording, and to urge at once their substitution.

‡ See "Supplement," Note I. § See "Supplement," Note J.

"Relay" and "receiving" circuits.—The somewhat controverted question as to the true origin of the relay system of electrical communication has been purposely reserved for a concluding discussion. Though unquestionably a valuable adjunct in distant intercourse, the "relay" is not here treated as an essential feature of the electric telegraph, since land-lines of 600 miles, and by the ocean system cables of 2,000 miles, are easily made operative in a single stretch or circuit.

Henry's original contrivance of a special compound circuit in 1835, (already noticed,) by no means precluded an equally original invention by Professor Morse some years later of a different arrangement of conjoined circuits. Nor is it at all surprising that a combination (in itself sufficiently obvious) should spontaneously occur to several minds if so circumstanced as to feel a need for it. There is reason to believe that Morse, like Wheatstone, independently invented his application of the general idea, and probably about the same time, in the spring of 1837.*

To do justice however to each party, it is all-important to discriminate carefully between the actual results attained by each. Henry had simply the philosophic plan of employing a weak magnetic power to act as a distant trigger for a great magnetic power, (one therefore of short circuit,)—and there stop.† Wheatstone, employing a delicate arrangement of silent galvanometer needle at the distant station, felt the necessity of promptly calling attention to the visual signal by an audible alarm; hence this feeble power was used also as the trigger to bring into action a much shorter and more powerful electro-magnetic circuit, —but merely as a *call*, and there stop. Morse, requiring a stronger signaling duty (in the use of a recording lever) than the length of the circuit would probably permit, conceived the idea of a division of the circuit into several shorter ones; each successive circuit to be *of the same kind* as the preceding. He thus *first* produced a true "relay," and this too without a knowledge of anything similar having been previously exhibited by Professor Henry as a lecture-room experiment before his college classes. It may therefore be affirmed that Henry, feeling no occasion for *extending* a telegraphic line, had probably no idea of a "relay," properly so called, when he first devised his combination of an "intensity" circuit with a "quantity" circuit; that Professor Morse, by his own declaration, had certainly no conception of a local receiving "quantity" magnet when subsequently he first devised his combination of a series of equal "intensity" circuits; and that Wheatstone had as little idea of either a "receiving" or a "relay" magnet when (in con-

*It even appears (from the unfortunate controversy between Messrs. Cooke and Wheatstone as to the priority and value of their respective contributions) that the two English copartners each independently invented the "relay" alarum. (*Professor Wheatstone's Answer* to Mr. Cooke's pamphlet. Republished in Cooke's "*Electric Telegraph*," etc. part i, p. 55, foot-note.)

†"My object in the process described by me was to bring into operation a large 'quantity' magnet connected with a 'quantity' battery in a local circuit, by means of a small 'intensity' magnet, and an 'intensity' battery at a distance." (*Smithsonian Report* for 1857, p. 112.)

junction with Cooke) he devised a "quantity" circuit supplementary to his "intensity" circuit for the sole purpose of calling "attention."

Professor Morse in his answer to the *twelfth cross-interrogatory* (in his deposition taken February 6, 7, and 8, 1851), in the case of "B. B. French and others *vs.* H. J. Rogers and others," has made the following statement: "If by the question is sought the date of my invention of breaking and closing one circuit by another, I answer in 1836 [?]. I exhibited the same in operation [?] in the spring of 1837. If by the question is sought the date of my invention of a short circuit to be used at the extremities of the line, I answer in May of 1844. If by the question is sought the date of a still greater improvement, to wit, that of placing short circuits on the margin (so to speak) of the main line, all of them to be operated simultaneously, I answer that the idea of such an improvement first presented itself to my mind in the beginning of the year 1844.* . . . The short circuits at the extremity of the main line were first used on the line between Washington and Baltimore, in May, 1844."†

These deliberate statements of Professor Morse distinguish very explicitly between the "relay" of magnets for "breaking and closing one circuit by another," and the "receiving" magnet of "a short circuit at the extremities of the line." And as a fact of public record, Morse patented the first of these devices June 20, 1840; (No. 1647;) while he did not patent the latter device (the "receiving" magnet of a local circuit) till about six years later, April 11, 1846: (No. 4453.)

On the same subject, Professor Gale has stated in his deposition: "The said Morse always expressed his confidence of success in propagating magnetic power through any distance of electric conductors which circumstances might render desirable. His plan was thus often explained to me. Suppose (said Professor Morse) that in experimenting on twenty miles of wire we should find that the power of magnetism is so feeble that it will but move a lever with certainty but a hair's breadth; that would be insufficient it may be to write or print, yet it would be sufficient to close and break another or a second circuit twenty miles farther; and this second circuit could in the same manner be made to break and close a third circuit twenty miles farther; and so on around the globe."

This is a very clear presentation of the "relay" of circuits. But with a slight confusion of idea Dr. Gale proceeds: "This general statement of the means to be resorted to, now embraced in what is called the '*receiving magnet*,' to render practical—writing or printing by telegraph through long distances, was shown to me more in detail early in the spring of the year 1837." To the same effect, nearly a quarter of a

* [Steinheil, in 1837 (seven years earlier), had adapted his registering galvanometer "to repeat and render permanent *at all parts of the chain* where an apparatus like that above described is inserted," the information transmitted to the terminus. (Sturgeon's *Annals of Electricity*, etc. April, 1839, vol. iii, p. 520.)]

† *Deposition of Samuel F. B. Morse*, Circuit Court of the United States for the eastern district of Pennsylvania, April session, 1850, No. 104, "Complainant's Evidence," pp. 182, 183.

century later, Dr. Gale states that "Before lines of telegraph were set up, it was anticipated that in long lines the ordinary current of electricity might not be strong enough to work the magnet at such distance, so as to write, but would be so strong as to open and close a side or local circuit, as suggested by Professor Henry. This mode of using one electric circuit and magnet to open and close another electric circuit (either for extending the main circuit to greater distances or to operate any local circuit), although not in the machine when I first saw it, was *discussed* in an early part of 1837, before any lines had been constructed."*

In both these accounts, Professor Gale has inadvertently (though not unnaturally) confounded together two entirely distinct inventions, involving different arrangements and purposes;—the "relay" circuit and magnet (of the "intensity" order), and the "receiving" circuit and magnet (of the "quantity" order); although Professor Morse himself distinctly declared he had no conception of the latter arrangement in 1837, having invented it "in May of 1844."

While the first invention of the special application called the "relay" is thus unhesitatingly ascribed to Professor Morse, the practically much more important arrangement of the terminal or local short circuit "quantity" magnet for reinforcing the power of the "intensity" magnet, must as unhesitatingly be claimed for Henry; and as an invention several years prior to that of Morse, it would by the well-known principles of patent-law, have generically subordinated the special application of the latter. Although Henry did not technically "perfect the invention," it remains none the less true that every "receiving magnet" in use throughout our own and other countries is but the *obvious* application of Henry's experimental junction of the two circuits, exhibited eleven years before it entered into Professor Morse's patent of April 11, 1846.

As indicative of the relative importance of these two inventions,—the Henry "receiving" magnet and the Morse "relay" of circuits, it may be stated that on the extended lines of the "Western Union Telegraph Company," there are now 13,745 of the former in actual operation, and only 228 of the latter; being 60 of the Henry "receivers" for each of the Morse "repeaters." And in remarkable confirmation of Henry's early anticipations of the capacity of his "intensity" magnet to be operated under judicious conditions directly through a distance of several hundred miles, it is the "accomplished fact" to-day that numerous single circuits ranging from 500 to 600 miles in length, are in actual use in the United States, operated by his magnet. The telegraph-line from New York to New Orleans, (upward of 1,500 miles,) is worked in three links or circuits (connected by *two* relays or repeaters); the last circuit, from Chattanooga, Tenn. to New Orleans, La. being 638 miles long.†

* Memorial of S. F. B. Morse, Washington, 1875, p. 19. On the question of the *date* of Professor Morse's "Relay", see "Supplement," NOTE K.

† These interesting facts are communicated by the accomplished telegraphic expert, Mr Frank L. Pope (of the Western Union Telegraph Company), a vice-president of the American Electrical Society: author of "Modern Practice of the Electric Telegraph:" &c.

Among examples of "magnetic" telegraphs which might properly here receive a passing notice, are the four following:

1837. The so-called "mechanical" or chronometric telegraph of Mr. William F. Cooke, of London, comprising two synchronously revolving cylinders (or escapements) at the two stations, arrested simultaneously by a magnetic armature detent, somewhat after the general principle of Ronalds's synchronous dials of 1816, previously mentioned. This form of dial telegraph was worked by Mr. Cooke in April, 1837.*

1837. The first letter-printing telegraph, devised by Mr. Alfred Vail, of New Jersey, in September, 1837, comprising a printing-wheel provided with spring type for the letters of the alphabet, projecting radially from its periphery, and corresponding with the teeth of an escapement wheel on the same shaft or axis, driven by ordinary clock-work, and regulated by a pendulum. The pendulum oscillating as a free armature between two electro-magnets, was arrested by one of the magnets when the desired letter was reached, and another electro-magnet, with lever armature, simultaneously drew down the spring type of the letter-wheel upon the fillet of paper beneath it.† This ingenious arrangement like the dial telegraph of Ronalds, and that of Cooke (independently contrived but a short time previously), required a synchronous movement of the clocks and their pendulums at the two stations. Eighteen years later, a printing telegraph on the same principle was very successfully worked out and operated by Mr. David E. Hughes, of Kentucky.

1838. The electro-magnetic chemical telegraph of Mr. Edward Davy, of London, comprising a chemically marking or recording cylinder, operated by a clock-work escapement and the armature of an electro-magnet. Relays of circuits were also included, operated by a galvanometer needle.‡

1839. The dial telegraph of Prof. Charles Wheatstone, of London, completed by him in November, 1839, comprising an escapement and index operated by the step-motion of an electro-magnetic armature. In this arrangement, the synchronous motions and indicating positions on the terminal dials were effected entirely by the specific number of galvanic impulses given to the transmitting and receiving escapements.§ The principle of this transmission was in 1846, skillfully and successfully applied by Mr. Royal E. House, of Vermont, to a "printing telegraph."

* "Mr. Cooke's Case," before the arbitrators. *The Electric Telegraph*, etc. by W. F. Cooke, part ii, p. 23. It appears that this arrangement was devised by Mr. Cooke in 1836.

† *The American Electro-magnetic Telegraph*, by Alfred Vail, 1845, pp. 159–171.

‡ The *English patent* of Edward Davy, July 4, 1838, No. 7719.

§ "Professor Wheatstone's Case," before the arbitrators, in 1840, p. 101.

GENERAL SUMMARY.

From the foregoing partial history of the origin and development of the electro-magnetic telegraph, it is sufficiently demonstrated that its successful introduction has been effected by a considerable number of independent contributions. The leading preparatory investigations and discoveries which opened the way for the telegraph, (though with no such utilitarian end in view,) may be held to be:

1st: The discovery of galvanic electricity by Galvani (1786–1790).

2d: The galvanic or voltaic battery by Volta (1800).

3d: The directive influence of the galvanic current on a magnetic needle by Romagnosi (1802), and by Oersted (1820).

4th: The galvanometer by Schweigger (1820), the parent of the needle system.

5th: The electro-magnet by Arago and Sturgeon (1820–1825), the parent of the magnet system.

Passing these, the next most important series of steps in the evolution of our present system of telegraphy, and having a more or less conscious reference thereto, are:

First, and most vital: Henry's discovery in 1829, and 1830, of the "intensity" or spool-wound magnet, and its intimate relation to the "intensity" battery; whereby its excitation could be effected to a great distance through a very long conducting-wire.*

Second: Gauss's improvement in 1833, (or probably Schilling's improvement considerably earlier,) of reducing the electric conductors to a single circuit, by the ingenious application of a dual sign so combined as to produce a true alphabet.†

Third: Weber's discovery in 1833, that the conducting wires of an electric telegraph could be efficiently carried through the air, without any insulation except at their points of support.

Fourth: As a valuable adjunct to telegraphy, Daniell's invention of a "constant" galvanic battery in 1836.

Fifth: Steinheil's remarkable discovery in 1837, that the earth may form the returning half of a closed galvanic circuit, so that a single conducting-wire is sufficient for all telegraphic purposes.

Sixth: Morse's adaptation of the armature of a Henry electro-magnet as a recording instrument in 1837,‡ and in connection therewith the im-

*Subordinated to this important step, the use of the armature as the signaling device and the first adoption of an acoustic signal might be mentioned. If Morse's "relay" be judged by any as of sufficient importance to rank with the more essential elements, then Henry's earlier and still more important device of the terminal short circuit magnet of "quantity" must not be overlooked.

†The probable anticipations of this,—by Lomond in 1787, by Cavallo in 1795, and by Dyar in 1825,—are here neglected, as neither sufficiently definite, nor as perhaps practically influential on the progress of telegraphy; though this recurrence of idea should certainly not be lost sight of in any history of the origins of inventions.

‡September of 1837 is fixed upon as the earliest date on which an actual register of intelligible signs was made by Professor Morse. (New York *Journal of Commerce*, September 7, 1837.) These signs were not *alphabetical*, but were zig-zag markings representing numerals.

provement in 1838, on the Schilling, Gauss, and Steinheil alphabets, of employing instead of alternating signs (as in his first register), the simple "dot-and-dash" alphabet in a single line.*

As displaying the "movement of an age," it is interesting to observe that these six capital steps were all effected within the fruitful period of a single decade. If we except the first of these—the inaugurating advance, without which no electro-magnetic telegraph would have been practicable,† it will probably be difficult for the impartial historian to award to the succeeding five contributions their respective value and just desert.

The earlier needle type of the electro-magnetic telegraph, as developed by Schilling and by Gauss, has found its special and appropriate application in extended ocean-lines; and indeed without such development, it is doubtful whether we could have had a transatlantic telegraph. It is well for the exclusive partisans of the "American system" to reflect that in the operation of these submarine cables there enters no element of Morse's instrument. The receiving and indicating mechanism devised by Gauss and Weber, and introduced some ten years earlier, is essentially that in use to-day on either shore of the Atlantic Ocean. The signals of the earlier invention are equal right and left deflections of an exceedingly delicate reflecting galvanometer; the signals of the later invention are the unequal contacts of an electro-magnetic armature.

Many other telegraphic developments—not within the object of this summary, such as the various modifications of the galvanometer system, the ingenious arrangements of dial indicators, and above all—as most ingenious of all—the printing telegraphs, (originating as we have seen, with Alfred Vail,) present what may be called highly organized varieties of the art; but varieties which notwithstanding the rare order of inventive intelligence expended upon them, and the great value possessed by them in special applications, do not promise to exercise a corresponding influence upon the future of telegraphy. The wonders of multiplex telegraphy (the simultaneous transmission of two or even four or more communications in either direction over the same wire), and of vocal telegraphy (the transmutation and transmission of human speech by electric waves in the telephone), lie still more beyond the scope of this review.

In conclusion, an early averment in this historic sketch, as to "the growth of the electric telegraph," may be repeated in the language of a later writer. "The history of the subject thus far shows us that no single individual can justly claim the distinction of having been the

* Professor Morse's first use of the alphabet was made in January, 1838. (New York *Journal of Commerce*, January 29, 1838; also Prime's *Life of Morse*, 8vo, New York, 1875, p. 331.) On the subject of "Alphabetic notation" see "Supplement," NOTE L.

†Wheatstone himself does not appear to have fully realized the significance and value of Henry's researches till 1837. The simple electro-chemical telegraph might have been successfully developed without the discovery of the "intensity" magnet, and may yet prove in practice a formidable competitor with it.

inventor of the electric telegraph. It was in fact a *growth*, rather than an *invention*, the work of many brains, and of many hands." (Prescott's *Electricity and the Electric Telegraph*, 1877, chap. xxix, p. 420.)

But amid the galaxy of brilliant names who prepared the success and organized the triumph for the execution of skillful artisans, none stands higher, or shines with more resplendent luster, than that of

JOSEPH HENRY.

SUPPLEMENT.

NOTE A. (From p. 263.)

THE WORTH OF ABSTRACT RESEARCH.

The eminent natural philosopher Dr. Thomas Young, has well remarked: "No discovery however remote in its nature from the subjects of daily observation, can with reason be declared wholly inapplicable to the benefit of mankind. . . . Those who possess the genuine spirit of scientific investigation and who have tasted the pure satisfaction arising from an advancement in intellectual acquirements, are contented to proceed in their researches without inquiring at every step what they gain by their newly discovered lights, and to what practical purposes they are applicable. They receive a sufficient gratification from the enlargement of their views of the constitution of the universe, and experience in the immediate pursuit of knowledge that pleasure which others wish to obtain more circuitously by its means."*

In a similar spirit, Oersted expressed his clear perception in an anniversary address delivered in 1814, before the University of Copenhagen, that "The real laborer in science chooses *knowledge* as his highest aim. A love of knowledge, (which some are frequently obliged to place secondary to other duties,) with the man of science must be the occupation of his life; he is dedicated to nourish the holy flame of wisdom which shall diffuse its rays amidst the rest of mankind; it is his nightly lamp which shall enlighten the earth." †

And with no less earnestness and force, our own Henry declared: "While we rejoice that in our country above all others so much attention is paid to the *diffusion* of knowledge, truth compels us to say that comparatively little encouragement is given to its *increase*. . . . As soon as any branch of science can be brought to bear on the necessities, conveniences, or luxuries of life, it meets with encouragement and reward. Not so with the discovery of the incipient principles of science: the investigations which lead to these receive no fostering care from the government, and are considered by the superficial observer as trifles unworthy the attention of those who place the supreme good in that which immediately administers to the physical needs or luxuries of life. But he who loves truth for its own sake, feels that its highest claims are lowered and its moral influence marred by being continually summoned to the bar of immediate and palpable utility." ‡

In a plea for the endowment of abstract science, William Swainson, the naturalist, justly observes: "If the depths of science are to be fathomed, and new discoveries brought to light, the task can only be achieved by those whose time is at their own command, whose attention is not divided or distracted by avocations purely worldly, and whose circumstances are such as to make them free from pecuniary cares. Talents fitting their possessors for such speculations must be of a high order, and they are consequently rare: § yet still more rare it is to find superadded to them the gifts of fortune. From whom then if abstract science is to be fostered and rewarded, is

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* *Lectures on Natural Philosophy*, lect. i, vol. i, p. 2.

† *The Soul in Nature.* Bohn's Scientific Library, 1852, p. 141.

‡ *Smithsonian Report* for 1853, p. 8.

[§ Dr. Peter Mark Roget has well observed: "Important discoveries in science seem often to arise from accident; but on closer examination it is found that they always imply the exercise of profound thought. As the fertility of the soil is essential to the germination and growth of the seed which the wind may have scattered on its surface, so it is principally from the qualities of mind in the *observer* that an observation derives its value and may be made eventually to expand into an important branch of science." (*Galvanism*, 8vo, London, 1832, chap. i, p. 1.)]

this encouragement to come? Certainly not from the public; for what the multitude cannot appreciate they cannot be expected to reward. If indeed the speculations of the philosopher can be turned into immediate advantage by the manufacturer or the merchant, the inventor is in a fair way of dividing profits with the applier; but we are not at present considering such cases. . . . That discoveries which eventually have proved extensively applicable to commerce were never so suspected when their first rudiments were developed, is too notorious to be disputed; for the *discovery* and the *application* of a new principle require very different powers of mind. . . . It is a maxim of the vulgar to esteem every requirement of this sort in proportion to the direct benefit it confers on their own interests."*

It is indeed too true that the prosecution of scientific truth for truth's sake only, is popularly held in little favor, and instead of receiving assistance, is even unblushingly decried by the would-be leaders of industrial opinion. Taking no lessons from the splendid triumphs of the past, which constantly assure us that the discovery of one age—naked and unprized, is the necessary foundation for the invention of the next, intelligent editors still repeat the annual cry in superior judgment on the proceedings of learned associations, "Dispense, gentlemen, with these barren and uninteresting papers, and give us something 'practical.'"

The average citizen, professing a patronizing admiration of "science," is able perhaps to appreciate the physics of machinery, and the chemistry of manufactures. Eager for the rewards which may be won from nature by her students, he would gladly be taught some new magneto-electric process for converting cellulose into bread, or "oleomargarine" into butter; and yet in ignorant ingratitude, would as gladly monopolize the very thunderbolt, when Science once has forged it for the use of Art.†

But let those incapable of conceiving a higher utility than the material, at least exercise that prudent reason they so much vaunt, and at least endeavor to secure for that self-interest they so diligently pursue, the character of an *enlightened* policy. The unpromising preparation for a possible magnetic telegraph was quietly advanced by a fine succession of earnest students (little known or respected by the multitude), who never paused to query "the *use* of it," and who (it is safe to say) would never have accomplished their beneficent mission had their investigations been directly prompted by the inspirations of a mercenary interest.‡ It may be confidently proclaimed as a firm induction from all our past knowledge, that so intimately bound together is the entire framework and system of the world, that no extension of our observation of the phenomena of nature and of our insight into the laws of nature (which are the laws of GOD), is not either a direct advancement in physical power and well-being, or a necessary stepping-stone to other truths which shall prove such.

"Scientific researches are often supposed by the uninformed to be of little or no real importance, and indeed are frequently ridiculed as barren of all practical utility. But nothing is more mistaken than this. The most valuable and productive of the arts of life, the most important and wonder-working inventions of modern times, owe their being and value to scientific investigations. By these have been discovered physical truths and laws, the intelligent application of which to practical inventions has given immense benefits to the world. The germs of these valuable improvements and inventions have been found and developed by scientific research,—the original forms of which have often seemed to the many to be as idle and useless as they were curious." §

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* Swainson, *On the Study of Natural History* (Cabinet Cyclopædia), part iv, chap. ii, sects. 244, 245, pp. 354–357.

† "Science has scattered her material benefits so lavishly whenever she has been in presence, that no small number of her followers and all the multitude have left off gazing on the resplendency of her countenance, in their eager scramble for her gifts." (*Quarterly Review*, June, 1841, vol. lxviii, p. 185.)

‡ Of those attempting the interrogation of nature "on account of the advantage and benefit to be derived from it," it may be said in Bacon's happy simile: "Like Atalanta, they leave the course to pick up the golden apple, interrupting their speed and giving up the victory." (*Novum Organum*, book i, aphorism 70, Bohn's edition, 1858, p. 407.)

§ Report of special committee of the Board of Regents, on the distribution of the income of the Smithsonian fund. *Smithsonian Report* for 1853, p. 86.

And to the same effect let us quote in conclusion a few of Henry's urgent utterances. "Every well-established truth is an addition to the sum of human power; and though it may not find an immediate application to the economy of every-day life, we may safely commit it to the stream of time, in the confident anticipation that the world will not fail to realize its beneficial results."*

"Unfortunately there has always been in England and in this country a tendency to undervalue the advantages of profound thought, and to regard with favor only those investigations which are immediately applicable to the wants of the present hour. But it should be recollected that the scientific principles which at one period appear of no practical value, and are far removed from popular appreciation, at another time in the further development of the subject, become the means of individual prosperity and of national wealth."†

"The progress of society and the increase of the comfort and happiness of the human family depend as a basis on the degree of our knowledge of the laws by which Divine wisdom conducts the affairs of the universe. He has created us with rational souls, and endowed us with faculties to comprehend in some measure the modes in which the operations of nature are effected; and just in proportion to the advance we make by patient and persevering study in the knowledge of those modes or laws, are we enabled to apply the forces of nature to our own use and to avert the dangers to which we are exposed from our ignorance of their varied influences. Nearly all the great inventions which distinguish the present century, are the results immediately or remotely of the application of scientific principles to practical purposes; and in most cases these applications have been suggested by the student of nature, whose primary object was the discovery of abstract truth. The statement cannot be too often repeated, that each branch of knowledge is connected with every other, and that no light can be gained in regard to one which is not reflected upon all. Thus researches which at first sight appear the farthest removed from useful application, are in time found to have an important bearing on the advancement of art, and consequently on the progress of society."‡

"The world generally has failed to recognize the importance of abstract scientific truths. Although these truths constitute the most important elements of modern civilization, since they give man power and control over the inherent forces of nature, and enable him to render these the obedient slaves of his will,—yet there is even at this time, no country (however intelligent it may appear in other respects) that has made adequate provision for the discovery and development of these important principles."§

NOTE B. (From p. 273.)

THE ORIGIN OF THE GALVANOMETER.

In 1808, Johann Solomon Christian Schweigger, professor of natural philosophy at Nuremberg, and afterward at Halle, published a memoir "On the employment of the magnetic force for measuring the electrical." From the somewhat obscure description it appears however that the instrument he had devised was simply an "electroscope" for indicating the static repulsion of ordinary or mechanical electricity; the magnetic needle, armed at each end with a brass button, being mounted on an insulated stand or pivot, and used as a substitute for the torsion electrometer of Coulomb.‖ This arrangement therefore involved no principle of the galvanometer.

In 1811, De la Rive, in a letter to the editors of the "Bibliothèque Britannique," recounting some experiments, applied the term "galvanometer" to an instrument for

* *Smithsonian Report* for 1856, p. 20.

† *Agricultural Report* of Commissioner of Patents for 1857, p. 420.

‡ *Smithsonian Report* for 1859, pp. 14, 15.

§ *Smithsonian Report* for 1866, p. 16.

‖ Gehlen's *Journal für die Chemie und Physik*, 8vo, Berlin, 1808, vol. vii, pp. 206–208.

measuring the quantity of the galvanic current by its decomposing energy.* Dr. Schweigger, in a notice of this paper, remarked that he had previously measured the battery force by the quantity of gases evolved from water in a given interval.† These experiments likewise, have evidently no relation to the present use of the term "Galvanometer."

Nine years earlier than this however, (or six years before Schweigger's needle electrometer,) the galvanic deflection of the magnetic needle had been distinctly observed and accurately recorded. For more than a century, repeated endeavors had been made to discover some relation between the magnetic and the electric attractions and repulsions, or to unite them by a single law. In 1774, a prize was offered by the Academy of Bavaria for the best examination of and dissertation on the question, "Is there a real and physical analogy between electric and magnetic forces?" Professor J. H. Van Swinden, of Franeker, Holland, one of the successful competitors, supported the conclusion that the similarities were entirely superficial, and that the two powers were essentially different in kind. On the other hand, Professors Steiclehner and Hubner contended that analogies so curious must imply a single agent.‡

But the true reaction between these agencies could not well be exhibited until after 1800, when Volta devised his galvanic battery; which for the first time enabled physicists to employ a *continuous* electric current. Gian Domenico Romagnosi, a native of Northern Italy, a celebrated publicist and author of several works on historical, legal, and political philosophy, was led near the close of the last century to occupy himself for several years with scientific investigations. The electrical problem attracted his attention, and after varied experiments with the aid of the new galvanic appliance, his versatile activity was partly rewarded; he being first of physical inquirers to make the capital discovery of the singular directive influence exerted by the galvanic current on a magnetic needle. This new phenomenon—of which he could not anticipate the importance or the consequences, was announced in the "Gazzétta di Trento" of August 3, 1802, an Italian newspaper published at Trent, in which city he had for many years resided.§ If the channel of publication for a contribution to science of such value was unfortunate, the account was at least republished in forms better suited to arrest attention from the learned.

In a work of some note and merit, entitled "Essai Théoretique et Expérimental sur le Galvanisme," by Prof. Giovanni Aldini (a nephew of Galvani), quarto, published at Paris in 1804, the author, at page 191, alluding to the supposed magnetic influence of a galvanic circuit, states, "This new property of galvanism has been confirmed by M. Romanesi, a physicist of Trent, who has observed that galvanism produces a declination of the magnetic needle." This work was republished shortly afterward in two volumes octavo.

In the "Bibliothèque Universelle" (Sect. *Sciences et Arts*), January, 1821, (shortly after Oersted's announcement,) at page 75, attention is called to Aldini's Treatise on Galvanism, and the passage above given is quoted. The same notice and citation are also published in Gilbert's "Annalen der Physik," 1821, vol. lxviii, page 208.

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* *Bibliothèque Britannique*, for February, 1811, vol. xlvi.

† "On a Galvanometer." Schweigger's *Journal für Chemie und Physik*, 8vo, Nürnberg, 1811, vol. ii, part 4, pp. 424–434.

‡ Notwithstanding the plausibility of this supposition, it remains to the present day entirely unconfirmed. The conclusion of Van Swinden was correct. The only approach to a closer analogy since obtained, is the remarkable fact discovered by Ampère in 1820, that two insulated wires, free to move, through which electricity *is flowing* in the same direction, attract each other like two dissimilar magnetic poles; and that they repel each other when their currents are reversed, like two similar magnetic poles. But the differences between these forms of attraction are still so radical, as to incline some physicists to the opinion that the one (that of magnetism) is inherent and indestructible, and the other (that of electricity) is a merely kinetic or dynamic phenomenon: while others would regard the two as both kinetic.

§ Romagnosi was chief-justice at Trent, from 1791 to 1794; and in December of 1802, not long after his scientific achievement, he was made professor of law in the University of Parma.

In a still more popular work on galvanism, by Prof. Joseph Izarn, entitled "Manuel du Galvanisme," etc. octavo, published at Paris, in 1805, in section ix, at page 120, it is also stated: "According to the observations of Romagnési, a physicist of Trent, a magnetic needle being submitted to a galvanic current undergoes a declination." This work is referred to in a discussion by Mr. Latimer Clark, of London.* Lastly, in the memoir of Romagnosi contained in the "Nouvelle Biographie Générale" (edited by Hœfer), vol. xlii, pages 574, 575, it is mentioned, "He discovered the deviation of the magnetic needle by galvanism."

Although this pregnant discovery of Romagnosi appears to have been known both to Dr. Sœmmering and to Baron Schilling in 1815, yet to neither of them did it suggest any applicability to the purpose of telegraphy. Dr. Hamel, of St. Petersburg, in his interesting account of the early history of the telegraph, informs us: "I have been endeavoring to find out from the papers of Sœmmering whether he and Baron Schilling might have had a knowledge of the Italian Gian-Domenico Romagnosi's important discovery made many years ago, that the magnetic needle deviates from its normal direction when under the influence of the galvanic current, and of which he had published an account in a newspaper at Trent on the 3d of August, 1802. . . . I found that Baron Schilling, immediately after his return to Munich in 1815, communicated to Sœmmering the little book, 'Manuel du Galvanisme,' by Joseph Izarn, professor of natural philosophy at the Lycée Bonaparte, which was printed in Paris in 1805, and in which, on page 120, mention is made of Romagnosi's discovery. I have also seen a note from Sœmmering mentioning that he had read this treatise with attention. I came however to the conclusion that neither to Sœmmering nor to Baron Schilling, had any idea of a practical application of Romagnosi's observation presented itself."† Nor is this at all surprising: for the similar discovery and announcement by Oersted in 1820, would just as little have suggested any practical method of communicating intelligence to a distance. And indeed had the experiment been attempted, it would have resulted in absolute failure. It needed the keen brains and active hands of a succession of profound investigators,—of Schweigger, and Ampère, and Arago, and Sturgeon, and Henry,—to develop fully the twofold capacity of electro-magnetism.

To the natural inquiry why the very same announcement which—made at the beginning of the century—fell as it were "still-born," should when again made eighteen years later, have sprung into so exuberant and active a vitality, the answer seems to be,—first, the greater care taken by Oersted, the later husbandman, to scatter the seed broadcast over Europe;‡ and secondly, the riper condition of the intellectual soil, at the later Spring. Romagnosi's work would seem to have been prematurely attempted; while Oersted's, no more meritorious, had the good fortune to be taken up and fostered by still more scrutinizing coadjutors: and thus while the early sowing fell by the wayside or in stony places, the later sowing fell on good ground, well prepared; and there speedily followed at the hands of a diligent band of laborers an abundant and most precious harvest.

The question may possibly arise, could Oersted have probably had any intimation of Romagnosi's earlier cultivation of the same field? Considering how little the latter name is known among scientific men to-day, the question may be confidently answered in the negative. Dr. Hamel however has ventured the severe judgment: "I cannot forego stating my belief that Oersted knew of Romagnosi's discovery announced in 1802, which was eighteen years before the publication of his own observations. It was mentioned in Giovanni Aldini's (the nephew of Galvani's) book. . . . Oersted was in Paris in 1802, and 1803, and it appears from the book of Aldini, that at the time he finished it, Oersted was still in communication with him; for he

*_Journal of the Society of Arts_, April 23, 1858, vol. vi, p. 356.

†_Journal of the Society of Arts_, July 29, 1859, vol. vii, p. 605.

‡"Hans Christian Oersted, at Copenhagen, had directed the attention of the scientific world much more effectually than Romagnosi of Italy had done, to the fact that the magnetic needle deflects when a galvanic current comes near it." Dr. Hamel. (_Jour. Soc. Arts_. 1859, vol. vii, p. 606.)

says at the end (page 376), he had not been able to add the information received from Oersted, doctor of the University at Copenhagen, about the galvanic labors of scientific men in that country."*

All that is known of Oersted's simple, generous, and upright character, utterly repels any such dark suspicion: and the remarkable interval of eighteen years, which elapsed between the two dates of publication, negatives even the probability of plagiarism. It seems only wonderful that no other experimental physicist happened to hit upon the observation in all those years.†

In Sabine's treatise on the "Electric Telegraph," reference is made in a note to Izarn's "Manual of Galvanism" and to his statement of Romagnosi's early discovery:‡ and in the second edition (of its historical portion), published two years later, Sabine remarks: "The discovery of the power of a galvanic current to deflect a magnet needle, as well as to polarize an unmagnetized one, was known to and described as early as 1805 by Professor Izarn in his 'Manuel du Galvanisme.' . . . After explaining the way to prepare the apparatus, which consists in putting a freely suspended magnet needle parallel and close to a straight metallic conductor through which a galvanic current is circulating, he describes the effects in the following words: 'According to the observations of Romagnési, a physicist of Trent, a magnetic needle, being submitted to a galvanic current, undergoes a declination; and according to those of J. Mojon, a learned chemist of Genoa, unmagnetized needles acquire by this means a kind of magnetic polarity.' To Romagnési, physicist of Trent, therefore, and not as is generally believed, to Oersted, physicist of Copenhagen, (who first observed in 1820 the phenomenon of the deflection of a magnet needle by a voltaic current,) is due the credit of having made this important discovery."§

While this is undoubtedly a correct verdict, it remains none the less true that the rapid awakening of European physicists to the significance and importance of the principle of the galvanometer, was due entirely to its rediscovery and reannouncement by Professor Hans Christian Oersted in 1820.

NOTE C. (From p. 278.)

ANTICIPATIONS OF ELECTRO-MAGNETISM.

From the Treatises on Galvanism, by G. Aldini, published in 1804, and by J. Izarn, published in 1805, (previously noticed,) we learn that Giuseppi Mojon, (Joseph Moyon in the French,) a chemist of Genoa, on placing steel sewing-needles in connection with a galvanic battery observed that they became magnetic: (probably with transverse polarity.) The description is however very obscure. (Aldini, p. 191; Izarn, p. 120.)

"It deserves to be remembered," says Dr. Hamel, "that from Aldini's book it was known that the chemist Giuseppi Mojon, at Genoa, had before 1804 observed in unmagnetized needles exposed to the galvanic current, 'a sort of polarity'. Izarn repeats this also in his 'Manuel du Galvanisme;' which book was one of those that by order were to be placed in the library of every Lycée in France".‖

Still a quarter of a century earlier, in 1777, (now a century ago,) Giovanni Baptista Beccaria, a distinguished Italian natural philosopher, professor of experimental science at Turin, and author of several works on Electricity, in the course of his experiments

**Journal of the Society of Arts*, July 29, 1859, vol. vii, p. 606.

† "The invention all admired; and each how he
To be the inventor missed;—so easy seemed
Once found, which yet unfound, most would have thought
Impossible."
(Milton's *Par. Lost*, book vi.)

‡ *The Electric Telegraph*, by Robert Sabine, 8vo, London, 1867, part i, chap. iv, sec. 29, p. 22.

§ *History of the Electric Telegraph*, 2d edition (in Weale's Rudimentary Treatises), 1869, chap. iv, sec. 27, pp. 23, 24.

‖ *Journal of the Society of Arts*, 1859, vol. vii, p. 606.

"found that a needle through which he had sent an electric shock had in consequence acquired a curious species of polarity; for instead of turning as usual to the north and south, it assumed a position at right angles to this, its two ends pointing to the east and west."* This curious phenomenon (which if properly investigated might have led to the discovery of electro-magnetism) was exhibited by the action of common frictional or mechanical electricity: galvanism not having been discovered till some time later. It was probably this same transverse polarity that was afterward observed by Mojon.

. NOTE D. (From p. 287.)

HENRY'S SPOOL MAGNET IN EUROPE.

Among the physicists of Europe who repeated Henry's experiments on a similar scale, Claude S. M. Pouillet, professor of physics at the *École Polytechnique* and director of the *Conservatoire* at Paris, made in 1832, a magnet capable of sustaining 900 pounds. At the session of the *Société Philomatique* of Paris, for June 23, 1832, Pouillet gave an account of recent experiments made by him with an electro-magnet of large size, having several thousand feet of wire wound upon it. The following is the report of this communication published in the "Bulletin" of the Society for August of that year:

"M. Pouillet communicated to the Society the results of experiments which he had just made on the magnetization of round bars of iron, (bent in horseshoe form, and surrounded on the arms with iron wire of a length of several thousand feet,) by means of an electric current established in this iron wire. The magnetism thus excited in a magnet one foot in height, formed of a bar of iron two and a half inches in diameter, and wrapped with 4,000 feet of wire, is sufficiently strong to support a weight up to 900 pounds, even when the contact of the armature with the magnet is reduced to an edge: so that the magnetic force is in this case stronger than the molecular attraction.† Attending such magnetization, on a connection being made between the two extremities of the conducting wire, a spark and a strong shock are produced. In another experiment, two similar magnets similarly arranged, having been placed facing each other, and varied in distance from contact up to a separation of a foot, the magnetization of the one produced a magnetization of the other by induction; so as to effect an electric current and spark when the two extremities of the conducting wire were brought very close together. In the latter case there was felt also a vivid shock. This shock may be communicated through a platinum wire even to the distance of a hundred feet."‡

The source of this "intensity" magnet is as unmistakable as is that of the magneto-electric spark obtained by its means. Had the experimenter however divided his 4,000 feet of wire into 50 or 60 separate coils, arranging suitably his galvanic battery in "multiple arc" as a "quantity" battery, he would certainly have greatly increased the attractive force of his magnet, and rendered it comparable to Henry's Yale-College magnet in lifting-power.

Pouillet in the third edition of his *Eléments de Physique Experimentale*, published in 1837, gives a drawing of a double "intensity" magnet arranged like Henry's in a supporting frame, of which he says: "Figures 432 and 433 represent an electro-magnet

* P. M. Roget, Treatise on *Electro-magnetism*, 1832, chap. i, art. 6, p. 3. (This treatise is included in the "Library of Useful Knowledge," vol. ii.)

† [Notwithstanding the considerable range of distance through which magnetism acts, it is not probable that the aggregate magnetic tenacity of iron in any case amounts to more than a very small fraction of its cohesive tenacity.]

‡ *Seance* of 23d June, 1832. *Nouveau Bulletin des Sciences*, publié par la "Société Philomatique de Paris," livraison pour Août, 1832, p. 127. This brief notice, republished in Quetelet's *Correspondance Mathematique et Physique* de l'Observatoire de Bruxelles, 1832, liv. v, vol. vii, pp. 317, 318, is the only paper by Pouillet on the subject of magnetization by electric currents, contained in the Catalogue of the Royal Society. Presumably therefore his only contribution on the subject.

which I constructed in 1831; and which easily supports nearly one ton (more than a thousand kilogrammes) when submitted to the current of a strong battery of 24 pairs. It consists of two horse-shoes opposed to each other, formed of round bars from three to four inches (8 to 10 centimetres) in diameter, and from two to two and a half feet (60 to 80 centimetres) in total length. The two arms of each horse-shoe are enveloped with about 1,100 yards (one thousand metres) of copper wire 26 thousandths of an inch (two-thirds of a millimetre) in thickness. The same current traverses successively the 2,200 yards (two thousand metres) of wire; but the helices are so disposed as to bring their opposite poles together." And the author repeats that as soon as the current is established, the lower free magnet is attracted to the upper fixed magnet with such force as to lift "an enormous weight, often exceeding a thousand kilogrammes."*

The remark just made applies equally to this example of the Henry "intensity" magnet, that by the substitution of the multiple coil and the "quantity" battery, it should have equalled the Henry Yale-College magnet, if not his Princeton magnet.

There is however in this latter account, an evident error of date, which should be noted. The differences of detail (in every particular) between the two magnets referred to, preclude any suggestion of the latter being an inaccurately remembered account of the former. The systematic excess of the latter magnet in every element of construction and performance equally excludes the possibility of its having been devised by its author prior to his notice before the "Société Philomatique" (on the 23d of June, 1832) of his success in developing a magnetic power of 900 pounds. And the fact that Pouillet, in the *second* edition of his Elements of Experimental Physics published in 1832 ("revue, corrigée et augmentée"), makes no allusion whatever to such a magnet, may be taken as conclusive evidence that no such magnet (nor any other) was constructed by him in 1831.†

The error of statement, in his third edition of the Elements of Physics is easily explained as a simple inadvertence in trusting to memory for a precise date.‡

It may be accepted with tolerable certainty that Pouillet's later and larger magnet could not have been made earlier than the latter part of 1832. And yet this inadvertent antedating by one year (wholly unimportant though it be) has been very precisely reproduced in the fourth edition of Pouillet's Physics, published in 1844, in the fifth edition published in 1847, in the sixth edition published in 1853, in the seventh edition published in 1856, and presumably in every subsequent edition, as well as in the numerous translations of this popular work. The earliest date of publication of Pouillet's 900-pound magnet is August, 1832; of his second, or 2200-pound magnet, is 1837.

NOTE E. (From p. 289.)

HENRY'S EARLY TELEGRAPHIC EXPERIMENTS.

The following are some of the testimonials of living eye-witnesses to the operation of Henry's early electro-magnetic telegraph, during the years 1831 and 1832.

The Hon. Alexander W. Bradford, a former pupil of the Albany Academy under Henry's professorship in 1831, and who left the academy in 1832, thus recalls his academic experiences, a third of a century later: "And there was another professor, whose life has been spared, who rose with the sun to instruct his pupil eager after knowledge; who giving his heart and soul to the duties of the school, had yet time for exploring

* *Eléments de Physique Experimentale,* etc. par M. Pouillet, third edition, 2 vols. 8vo. Paris, 1837, liv. iii, sec. iv, chap. 5, art. 277. Vol. i, p. 572.

† *Eléments de Physique Experimentale,* etc. par M. Pouillet, second edition, 4 vols. 8vo. Paris, 1832.

‡ As if to magnify this accidental error, Dr. Lardner, in a popular text-book on the telegraph, makes the off-hand statement: "In 1830, an electro-magnet of extraordinary power was constructed under the superintendence of M. Pouillet at Paris. . . . With a current of moderate intensity the apparatus is capable of supporting a weight of *several tons.*" (Lardner and Bright's *Electric Telegraph,* 12mo., London, 1867, chap. ii, sec. 39, p. 22.)

the deep paths of science; who with his wires and silk thread winding miles of insulated copper in the commencement hall of the academy, patiently toiled his way to the demonstration of the magnetic power of the galvanic battery; and years before the invention of the telegraph, proclaimed to America and to Europe the means of communication by the electric fluid. I was an eye-witness to those experiments and to their eventual demonstration and triumph. In this commemorative festival, let us not forget to honor the name of Joseph Henry." *

On the same interesting occasion Dr. Orlando Meads thus recounted Henry's early triumph: "The older students of the academy in the years 1830, 1831, and 1832, and others who witnessed his experiments, which at that time excited so much interest in this city, will remember the long coils of wire which ran circuit upon circuit for more than a mile in length around one of the upper rooms in the academy, for the purpose of illustrating the fact that a galvanic current could be transmitted through its whole length so as to excite a magnet at the farther end of the line, and thus move a steel bar which struck a bell. This in a scientific point of view, was the demonstration and accomplishment of all that was required for the magnetic telegraph. The science of the telegraph was here complete. It needed only the inventive genius of Morse to supply the admirable instrument which was to make it available for practical use. . . . All honor to the inventor; but let us not forget that the click of the telegraph which is heard from every joint of those mystic wires which now link together every city, and village, and post, and camp, and station, all over this continent, is but the echo of that little bell which first sounded in that upper room of the academy. These facts are a part of the history of the academy; and it is fitting that on an occasion like this, so important a discovery made by one of her own sons, in her service, and under her own roof, should not be passed over in silence." †

Professor James Hall (in the same year in which he was president of the American Association, at its Albany meeting) addressed a letter to Professor Henry, dated January 19, 1856, reciting the following reminiscence:

"While a student of the Rensselaer School in Troy (New York), in August, 1832, I visited Albany with a friend, having a letter of introduction to you from Professor Eaton. Our principal object was to see your electro-magnetic apparatus, of which we had heard much, and at the same time the library and collections of the Albany Institute. You showed us your laboratory in a lower story or basement of the building, and in a larger room in an upper story, some electric and galvanic apparatus, with various philosophical instruments. In this room and extending around the same, was a circuit of wire stretched along the wall, and at one termination of this in the recess of a window a bell was fixed, while the other extremity was connected with a galvanic apparatus. You showed us the manner in which the bell could be made to ring by a current of electricity transmitted through this wire; and you remarked that this method might be adopted for giving signals by the ringing of a bell at the distance of many miles from the point of its connection with the galvanic apparatus. All the circumstances attending this visit to Albany are fresh in my recollection; and during the past years while so much has been said respecting the invention of electric telegraphs, I have often had occasion to mention the exhibition of your electric telegraph in the Albany Academy in 1832." ‡

On the occasion of a visit by Henry to the Albany Institute, about two years later than the date of the above letter, Professor Hall made public reference to the same vivid recollections. At a meeting of the Albany Institute, held Janauy 13, 1858, in a hall of the Albany Academy building, "Professor Hall called attention to the fact, in connection with the visit of Professor Henry, that in 1832 he had witnessed in this

* "Commemorative Address," on the celebration of the semi-centennial anniversary of the Albany Academy, June 23, 1863. *Proceedings*, etc. p. 48.

† "Historical Discourse", at semi-centennial anniversary of Albany Academy, June 23, 1863. *Proceedings*, etc. pp. 25, 26.

‡ Published in the *Smithsonian Report* for 1857, p. 96.

building illustrations by Professor Henry of his results in electro-magnetism. He saw here a wire of great length, through which Professor Henry transmitted a current of galvanic electricity, and made the current to exert its power in ringing a bell at the extremity of the wire. This was certainly the first establishment of the practicability of the magnetic telegraph."

"Professor Henry stated that he felt gratified at this public recognition of his early labors and discoveries in reference to the electric telegraph." *

Henry's primitive electro-magnetic telegraph (as already stated) was properly an *acoustic* telegraph. Morse's subsequent electro-magnetic telegraph was a *recording* telegraph, and it was this feature of automatic register which was always regarded by its inventor as the most characteristic and important element of his invention. "It was soon discovered, after the introduction of the Morse system of telegraph, that words could be read by the click of the magnet; but paper was used upon which the arbitrary alphabet of dots and lines was indented by the instruments, for all matters of business up to 1852, and by many lines even later; but at the present time there is scarcely an office of any importance in the United States where the paper is used to receive the record. Ten years ago the practice was almost invariable in the principal offices to employ an operator to read the dispatch from the long strips of paper as it came from the instrument; and a copyist who stood by his side took it down. Now the system is entirely changed. The operator reads by the click, and copies the message himself. By this means the expense is lessened nearly one-half, and the risk of errors in a far greater ratio."† To which it may be added, that the diminished duty of the armature enables a single circuit to be operated through double the distance practicable with the Morse recorder.

And thus it has come to pass that the Morse telegraph to-day, is (by reversion to a more primitive type) essentially an *acoustic telegraph.*‡ So that "the click of the telegraph heard all over this continent," is in Dr. Meads's expressive phrase, *functionally and in truth* "but the echo of that little bell which first sounded in that upper room of the Albany Academy."

NOTE F. (From p. 296.)

HENRY'S RELATION TO THE ENGLISH TELEGRAPH.

In consequence of the repeated disagreements between the English patentees, Messrs. Cooke and Wheatstone, (not long after their procurement of a joint patent in June, 1837,) as to their respective shares of originality and credit in the invention of the needle telegraph, "Articles of Agreement" were drawn up on the 16th of November, 1840, for the submission of their grounds of claim and of dissatisfaction, to the arbitrament of two referees, Marc Isambard Brunel, on the part of Mr. Cooke, and John Frederick Daniell, on the part of Mr. Wheatstone. And in December of 1840, the

* *Trans. of Albany Institute*, vol. iv, "Proceedings," p. 245.

† Prescott's *History of Electric Telegraph*, Boston, 1860, chap. v, pp. 92–93. To the same effect is the statement in his later work: "In the larger telegraph offices of the United States and Canada, the recording instrument, or register, is entirely dispensed with, and all communications are read by the sound made by the armature lever as it vibrates between the upper and lower stops." (Prescott's *Electricity and the Electric Telegraph*, New York, 1877, chap. xxx, p. 435.)

‡ Numerous patents have been granted for "sounders," having for their object the emphasizing or re-enforcement of the sound from the receiving key or armature impacts. Prescott, in his recent work, speaking of Thomson's ingenious and extremely delicate "siphon recorder," remarks: "It is somewhat curious that in the progress of telegraphic improvement, Morse's telegraph (the most valuable feature of which originally was considered to be its capacity for recording communications) should have been modified in practice into an acoustic semaphore, while Cooke's telegraph (originally a semaphore) should at length have been also modified into a recording instrument." (*Electricity and the Electric Telegraph*, chap. xxxii, p. 561.)

contestants presented to the said arbitrators the carefully prepared statements of their respective "cases."*

Mr. Cooke, in his "Statement of Facts to the Arbitrators," gave the following account of his telegraphic failure in February, 1837, which was precisely that encountered and announced by Barlow, some dozen years before: "I employed myself in trying experiments upon the electro-magnet, with a view to discover at what distance an electric current would excite the temporary magnetism required for moving the detent of the mechanism. For this purpose I adjusted above a mile of wire in the chambers of Mr. Lane, in Lincoln's Inn; *but the magnets and battery being ill proportioned,* my experiments were unsatisfactory."† The cause of failure stated, evidently represents his acquired knowledge in 1840, not that in 1837. It was the singular fatality of electro-magnetism confronting every early experimenter from Barlow downward, that whether the number of cells in the battery were increased, or whether the length of wire coiled around the magnet were extended, the effect upon the magnet in either case *rapidly diminished* after a certain short distance of circuit. Who then would think for a moment of compounding these enfeebling arrangements?

In the desperate emergency which seemed to impose an impassable barrier to his signal device, Mr. Cooke consulted successively three among the most eminent of British electricians: Professor Faraday, Dr. Roget, and Professor Wheatstone. The following is the continuation of his own account, from the "case" already quoted: "In this scientific difficulty I sought the assistance of Dr. Faraday, who advised me to increase the number of the plates of the battery proportionably to the length of the wires; an expedient which in some degree overcame the defect of the magnet.‡ I also consulted Dr. Roget upon the same scientific point. . . . Dr. Roget informed me that Professor Wheatstone had a quantity of wire at King's College, which might assist me in trying experiments upon the electro-magnet, and he advised me on that account to submit my difficulty to him." To the same effect, in his later pamphlet published in March, 1856, (more than fifteen years afterward,) he said: "This result was to be accomplished by means of an electro-magnet; and it was my inability to make the electro-magnet act at long distances which first led me to Mr. Wheatstone." §

At this point it is proper to turn to Professor Wheatstone's statement of the interview, in his own "case," as presented to the arbitrators at the same time, in December, 1840:

"I believe but am not quite sure that it was on the first of March, 1837, that Mr. Cooke introduced himself to me. He told me that he had applied to Dr. Faraday and Dr. Roget for some information relative to a subject on which he was engaged, and that they had referred him to me as having the means of answering his inquiries. . . . Relying on my former experience, I at once told Mr. Cooke that it would not and could not act as a telegraph, because sufficient attractive power could not be imparted to an electro-magnet interposed in a long circuit; and to convince him of the truth of this assertion, I invited him to King's College to see the repetition of the experiments on which my conclusion was founded. He came, and after seeing a variety of voltaic

* These documents, with the "award" rendered April 27, 1841, published immediately afterward, were some years later republished by Mr. Cooke (together with subsequent controversial pamphlets between the parties) in two octavo volumes, under the common title, "The Electric Telegraph: was it invented by Professor Wheatstone?" One volume, published in 1856, comprising the "Arbitration Papers" in full, is injudiciously designated "Part II." The other volume, published in 1857, embracing matter of a much later date, is improperly designated "Part I." This part comprises a reprint of "Mr. Cooke's First Pamphlet," published in December, 1854; of "Mr. Wheatstone's Answer," published in January, 1856; and of "Mr. Cooke's Reply," published in March, 1856.

† *The Electric Telegraph,* etc. by W. F. Cooke, part ii, sec. 46, p. 24.

‡ Faraday in his brilliant series of researches commencing in September, 1831, employed almost exclusively Henry's "quantity" magnet of numerous short coils; and hence naturally paid little attention to the feebler energies of Henry's "intensity" magnet.

§ Work above quoted, part i, pp. 198, 199.

magnets, which even with powerful batteries exhibited only slight adhesive attraction, he expressed his disappointment." *——" When I endeavored to ascertain how a bell might be more efficiently rung, the attractive power obtained by temporarily magnetizing soft iron first suggested itself to me. The experiments I made with the long circuit at King's College however led me to conclude that the attraction of a piece of iron by an electro-magnet could not be made available in circuits of very great length, and therefore I had no hopes of being able to discharge an alarum by this means." †

Not a little surprising is it that three savans so distinguished, all of them familiar in a general way with Henry's electro-magnetic researches published more than six years before, should each have failed to apprehend, or should have forgotten, the distinctly declared virtue of his "intensity" magnet. ‡ Henry, in 1829, and 1830, had fully demonstrated that while with a single galvanic pair a small magnet surrounded with a long wire showed very feeble magnetism (as compared with one of short coil), with a "trough" battery of many pairs it exerted a stronger attraction after the current had passed through 1,060 feet of wire in the circuit than when the coil was directly connected with the battery. He had announced: "From these experiments it is evident that in forming the coil we may either *use one very long wire* or several shorter ones, as the circumstances may require; in the first case our galvanic combination *must consist of a number of plates*, in the second it must be formed of a single pair." And he had expressly called attention to the fact that the former arrangement "is directly applicable to the project of forming an electro-magnetic telegraph." §

Mr. Cooke continued the narrative in his "case" as follows: "On many occasions during the months of March and April, 1837, we tried experiments together upon the electro-magnet; our object being to make it act efficiently at long distances in its office of removing the detent. The result of our experiments confirmed my apprehension that I was still without the power of exciting magnetism at long distances. . . . In this difficulty we adopted the expedient of a secondary circuit, which was used for some time in connection with my alarum." ‖

It is at this period that Henry made his first visit to England; and in London he formed an acquaintance with Faraday, with Roget, and with Wheatstone, with each of whom he had many pleasant and familiar interviews, and for each of whom he ever entertained a warm personal regard. He has left the following account of his communication with the professor last named:

"In February, 1837, I went to Europe; and early in April of that year, Professor Wheatstone, of London, (in the course of a visit by myself to him in King's College, London, with Professor Bache, now of the Coast Survey,) explained to us his plans of an electro-magnetic telegraph; and among other things exhibited to us his method of bringing into action a second galvanic circuit. This consisted in closing the second circuit by the deflection of a needle so placed that the two upward projecting ends of the open circuit would be united by the contact of the end of the needle when deflected; and on opening or breaking the circuit so closed, by opening the first circuit and thus interrupting the current, the needle would resume its ordinary position under the influence of the magnetism of the earth. I informed him that I had devised another method of producing effects somewhat similar. This consisted in

* ["Electro-magnets of the greatest power, even when the most energetic batteries are employed, utterly cease to act when they are connected by considerable lengths of wire with the battery." (*Introduction to the Study of Chemical Philosophy:* by Prof. John Frederick Daniell, 2d ed. 1843, chap. xvi, sec. 859, p. 576.)]

† *The Electric Telegraph*, etc. by W. F. Cooke, part ii, sects. 268, 272, and 299, pp. 86, 87, and 93.

‡ Faraday refers to Henry's magnets in his *Experimental Researches*, etc. (Nov. 24, 1831), vol. i, art. 57, p. 15; and Roget refers to them in his excellent Treatise on *Electro-Magnetism*, 8vo. London, 1832, chap. x, sec. 161, p. 55.

§ Silliman's *American Journal of Science*, January, 1831, vol. xix, p. 404.

‖ *The Electric Telegraph*, etc. by W. F. Cooke, part ii, sec. 51, p. 27.

opening the circuit of my large quantity magnet at Princeton, when loaded with many hundred pounds weight, by attracting upward a small piece of movable wire with a small intensity magnet connected with a long wire circuit. When the circuit of the large battery was thus broken by an action from a distance the weights would fall; and great mechanical effect could thus be produced, such as the ringing of church-bells at a distance of a hundred miles or more,—an illustration of which I had previously given to my class at Princeton. . . . The object of Professor Wheatstone as I understood it, in bringing into action a second circuit, was to provide a remedy for the diminution of force in a long circuit. My object in the process described by me was to bring into operation a large quantity magnet connected with a quantity battery in a local circuit, by means of a small intensity magnet and an intensity battery at a distance." *

This important historic interchange of experiments and projects between Henry and Wheatstone, possesses an interest and a significance quite beyond that present in the contemplation of the writer. To Henry, the confidence imparted was striking only from the coincidence of separate inventions in the combination or conjunction of two circuits; in his own case by the agency of an "intensity" magnet at a distance, in the other case by the agency of a galvanometer needle at a distance.† But to Wheatstone, how different must have been the impression and suggestion! From the simple account of Henry's contrasted "intensity" and "quantity" magnets; of his telegraphic experiment in 1831,—the magnetic tapping of a bell through more than a mile of fine copper wire; of his daring faith in being able to ring heavy bells by a terminal "quantity" magnet, "*at a distance of a hundred miles or more!*" with what new interest and meaning must the earlier and neglected researches of Henry have been recalled. Who could doubt that with the unsolved problem of Mr. Cooke just fresh before him, with his active and fertile mind awakened, quick to seize upon and develop a new idea, (as well illustrated in his intercourse with Mr. Cooke,) who could doubt that the presentation above recorded (in *April* of 1837,) must have been to him a new solution and a sudden revelation?

Surely some recognition of Henry's published researches was to be looked for in return for the unexpected but unquestionable benefit conferred. We search in vain for any such requital or acknowledgment. In amplifying his own "improvements" before the arbitrators, he says: "*But the most important point of all* was my application of the theory of Ohm to telegraphic circuits, which enabled me to ascertain the best proportions between the length, thickness, &c., of the multiplying coils and the other resistances in the circuit, and to determine the number and size of the elements of the battery to produce the maximum effect. With this law and its applications, *no persons who had before occupied themselves with experiments relating to Electric Telegraphs had been acquainted*"!‡ The "theory of Ohm" (announced in 1827), had avowedly no influence whatever on Wheatstone's researches—till after his interview with Henry, in April, 1837; nor was the "theory of Ohm" any more definitely applied, or any more implicitly confirmed, by the later English experimenter in 1837, than it had been by the earlier American experimenter in 1829, and 1830. And Professor Wheatstone's explicit declarations that in *March*, 1837, he found by experience that "sufficient attractive power could *not* be

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* *Smithsonian Report* for 1857, pp. 111, 112. As Prof. Alexander Dallas Bache was present on the occasion above mentioned, and as he was also subsequently a Regent of the Institution, under whose direct supervision and authority the above statement of Henry was published by the board, it may be regarded as having his implicit corroboration.

† Professor Wheatstone, in his "Answer" to Mr. Cooke's Pamphlet, says: "My experiments led me to believe that the motions of a needle could be produced at distances at which no effects of electro-magnetic attraction could be obtained." (Letter of October 26, 1840; reprint, p. 114.)

‡ "Professor Wheatstone's Case." *The Electric Telegraph*, etc. by W. F. Cooke, part ii, sect. 290, p. 91.

imparted to an electro-magnet interposed *in a long circuit*,"—that "the attraction of a piece of iron by an electro-magnet could *not* be made available in circuits *of very great length*," excludes absolutely and forever, all possibility of competitive claim to a discovery admittedly "the most important point of all" in the practical development of a real *telegraph;—the discovery of the "intensity" magnet.* Undoubtedly required to institute especial experiments in order to properly proportion his magnet and battery, Wheatstone was led by self-esteem to entirely overestimate the originality of such experiments, and correspondingly to underrate the value of Henry's instructions or suggestions.

Recurring to his plan of a terminal secondary circuit Professor Wheatstone re-iterates in the same document: "Having convinced myself that it was hopeless to expect to ring an alarum by the direct action of the electric current through a circuit of great length on an electro-magnet as ordinarily constructed, I began to think whether the effect required might not be produced in an indirect manner. It occurred to me that the difficulty would be overcome if a short circuit in which the electro-magnet of the alarum and a rather powerful electro-motor should be interposed, could be completed and broken at will by some action governed by the current in the long circuit. . . . These methods of completing the secondary circuit have lost all their importance and are scarcely worth contending about, *since my discovery* that electro-magnets may be so constructed as to produce the required effects by means of the direct current, even in very long circuits."

Again returning to this fatal theme, he repeats (having resolved to "carry out his investigations alone" without the co-operation of Mr. Cooke), "After this resolution had been taken, I commenced a series of researches *on the laws of electro-magnets*, and was fortunate enough to discover the conditions (*which had not hitherto been made the subject of philosophical inquiry*) by which effects could be produced at great distances. This rendered electro-magnetic attraction *for the first time* applicable in an immediate manner to telegraphic purposes." *—Notwithstanding that Henry, in 1830, had demonstrated—and on the first of January, 1831, had confidently announced to the scientific world, that his own original "intensity" magnet with a "trough" battery, was "directly applicable to the project of forming an electro-magnetic telegraph"!

This redundant iteration of original discovery, this reticence as to any similar investigation known to have been even *attempted* by Henry, scarcely permits the charitable suggestion of "unconsciousness." That his persistent claim should have misled his colleague, Professor Daniell, into incorporating in the text of his new edition of the "Chemical Philosophy" the following laudation, is perhaps not altogether to be wondered at: "Ingenious as Professor Wheatstone's contrivances are, they would have been of no avail for telegraphic purposes without the investigation (*which he was the first to make*) of the laws of electro-magnets when acted on through great lengths of wire." † Were the name of Henry inserted in the italicised parenthesis, the proposition stated would be beyond the reach of cavil or exception. Ingenious as Professor Wheatstone's contrivances were, *they would have been of no avail* for telegraphic purposes, without the investigation (which HENRY was the first to make)—of the laws of electro-magnets when acted on through great lengths of wire.

Mr. Cooke (to whom probably even the existence of Henry was unknown) makes the very expressive comment on the above passage from the "Chemical Philosophy" of the professor at King's College: "Mr. Daniell might have added that this investi-

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* "Professor Wheatstone's Case," as above cited, sect. 306, 314, and 333, pp. 94, 96, and 100.

† *Introduction to the Study of Chemical Philosophy*, second edition, 1843, chap. xvi, sect. 859, p. 576.

gation had not been commenced or thought of in *March*, 1837!"* In this pamphlet controversy which occurred between the joint-patentees some fourteen years after the memorable "award," Professor Wheatstone in his "Answer" (of January, 1856,) to Mr. Cooke's first pamphlet (of December, 1854,) somewhat more feebly re-echoes: "With this law and its applications *no persons in* ENGLAND who had before occupied themselves with experiments relating to electric telegraphs had been acquainted."†

The substance of the "award" rendered by the distinguished arbitrators April 27, 1841, in the matter of the Cooke and Wheatstone controversy, was that "Mr. Cooke *is entitled to stand alone* as the gentleman to whom this country is indebted for having practically introduced and carried out the electric telegraph as a useful undertaking, promising to be a work of national importance: and Professor Wheatstone is acknowledged as the scientific man whose profound and successful researches have already *prepared the public to receive it* as a project capable of practical application."‡ This decision—studiously non-committal as is its language, and even as interpreted by the extra-judicial letter of Professor Daniell, dated March 24, 1843, (two years subsequently,) cannot be regarded as sustaining the prominent theory of "Professor Wheatstone's Case," assuming priority of suggestion or of application of the needle telegraph, as compared with Mr. Cooke.

NOTE G. (From p. 305.)

THE AUTHORSHIP OF THE "MORSE ALPHABET."

It appears from various concurring testimonies, that the new recording instrument constructed for Professor Morse by Mr. Vail during October, November, and December, 1837, was entirely of his own design, without any suggestions from Professor Morse; and that its arrangement for discontinuous marking was specially contrived by its maker for an alphabet exclusively devised by himself; which he abstained from publicly claiming, owing to a delicate sense of obligation incurred by his contract with Professor Morse, to render him every assistance in perfecting the mechanical arrangements of the telegraph.§

That Professor Morse had no conception on the 3d of October, 1837, of the form of instrument contemplated by Mr. Vail, is clearly shown by his autographic "caveat" of that date. And his letter to Mr. Vail, of October 24th, announcing the completion of the numbered dictionary, (in which he wrote "we can now talk or write anything by numbers,") is equally conclusive evidence that at this later date, he was still unconscious of any alphabetic improvement.

An article in the New York Sun, by its editor, Mr. Moses S. Beach, (written in 1858,) under the heading "Honor to whom honor is due," makes the statement, "We will mention a few incidents connected with Professor Morse's own experience, which we have never seen in print, and which lose none of their interest from the unassuming modesty of the parties referred to." And after alluding to the assistance furnished

* Mr. Cooke's "Reply" to Professor Wheatstone's "Answer." (*The Electric Telegraph*, etc. by W. F. Cooke, part i, p. 199.) Dr. John Locke, of Cincinnati, who was in London in the summer of 1837, on his return to this country, having informed Professor Morse of Wheatstone's telegraphic experiments, Professor Morse in a letter from New York to Alfred Vail, at Speedwell, dated October 24, 1837, thus referred to the matter: "We have just heard that Professor Wheatstone has tried an experiment with his method, *twenty miles*, with success. We have therefore nothing to fear." (Prime's *Life of Morse*, chap. viii, p. 326.) At this date Professor Gale had operated the Morse instrument through only three miles of wire in the circuit.

† *The Electric Telegraph*, etc., by W. F. Cooke, part i, p. 57.

‡ *The Electric Telegraph*, etc., by W. F. Cooke, part i, p. 16: and part ii, pp. 214 and 268.

§ By the terms of the partnership in the telegraph, Mr. Vail agreed "to devote his personal services and skill in constructing and bringing to perfection, as also in improving, the mechanical parts of said invention, . . . without charge for such personal services to the other proprietors, and for their common benefit."

the inventor in his early imperfect experiments by the Messrs. Vail, the editor continues: "Alfred Vail entered into these experiments with his whole soul, and to him is Professor Morse indebted, quite as much as to his own wit, for his ultimate triumph. *He it was who invented the far-famed alphabet;* and he too was the inventor of the instrument which bears Morse's name. But whatever he did or contrived, went cheerfully to the great end. Alfred felt rewarded in seeing the gradual accomplishment of the dream."*

In an interesting article entitled "The first week of the Telegraph," written in 1869 for a New York monthly magazine, by Dr. William P. Vail, the following significant allusion to his deceased nephew, Mr. Alfred Vail, occurs: "The birth-time and the birth-place of the telegraph as a recording instrument of *intelligence*, . . . the parties who wrought the rude original plan into working order and gave it efficiency, the man *who invented the 'Morse alphabet'* (so called), and to whose ingenuity, mechanical skill, and tireless perseverance, the clock-work of the telegraph machine is largely due, . . . all this is well understood, and for the most part is written down, and the record some day in the near future must find its place in history, upon the true principle of *suum cuique*." †

It is noteworthy that neither the published statement made by the editor of the "Sun," nor that made by Mr. Vail's uncle in the "Hours at Home," (both widely circulated, and copied into other journals during Professor Morse's life-time,) was ever called in question by the celebrated telegrapher. His painful silence under the circumstances is not easily defensible.

Mr. Francis O. J. Smith, one of the partners in the original telegraph patent of Morse, (having had as capitalist and business manager, a one-fourth interest in the enterprise,) has also stated in a published letter, dated March 30, 1872, (not long before Professor Morse's death,) that the modified horizontal lever adapted "to emboss the alphabetic characters," was "neither invented nor combined in the telegraph by Professor Morse, but exclusively by our associate—Mr. Alfred Vail; although for reasons that will be satisfactory to most minds, they were never publicly credited to him, but have been claimed exclusively by Professor Morse as his own invented combination."‡

Dr. Gale, the only surviving member of the original partnership, states in a recent letter on the subject, that he does not distinctly remember whether the changed arrangement of the lever to a horizontal position in the new model constructed by Mr. Vail, was his exclusive invention or not.

In a biographical sketch of Alfred Vail by Mr. Frederick Brent Read, of Cincinnati, published in 1873, the writer states without qualification: "Alfred Vail first produced in the new instrument the first available *Morse* machine. He invented the first combination of the horizontal lever motion to actuate a pen or pencil or style, and the entirely new telegraphic alphabet of dots, spaces, and marks, which it necessitated; and he did so prior to September, 1837, the month when the old instrument passed into his hands for reconstruction. . . . The new machine was Vail's, not Morse's.

* *New York Sun*, for September 25, 1858. Republished in the *Weekly Sun*, for October 2, 1858. In a recent letter on the subject, Mr. M. S. Beach, the author of the above, states: "I was then personally acquainted with the Vails, and a not unfrequent visitor at the homestead in Morristown; besides of course having a personal acquaintance with Professor Morse, and with the telegraph managers generally. My impression is that the article was at the time approved for its exact statement—*never controverted*."

† Scribner's *Hours at Home*, September, 1869, vol. ix, pp. 435, 436. In response to an inquiry as to the evidence of Mr. A. Vail's invention of the "dot-and-dash" alphabet, Dr. W. P. Vail, the author of the above, declares in a recent letter, "It was so understood by all who were admitted to his intimacy. In a conversation with him shortly before his death, in 1859, he so assured me. I am not aware that Mr. Morse ever set up an adverse claim."

‡ A pamphlet entitled "*History Getting Right* on the invention of the American Electro-magnetic Telegraph," 1872, p. 21. It does not appear that Professor Morse ever did explicitly claim these inventions as his own.

The claim is clearly made then, that Alfred Vail in the first place invented an entirely new alphabet; secondly, he invented an entirely new machine in which was the first combination of the horizontal lever motion to actuate a pen or pencil or style, so arranged as to perform the new duties required with precision, simplicity, and rapidity; and thirdly, Vail invented, several years afterward [in 1844], the new lever and [grooved] roller which embossed into paper the wholly simple and perfect alphabetic characters which he alone originated."*

Numerous experiments with various kinds of pencils, fountain-pens, and inked roulettes, having shown their inefficiency for the uniform marking of the "dot-and-dash" alphabet, Alfred Vail at last boldly discarded all marking devices, and employed a blunt steel point near the end of the registering lever, playing directly ove- a narrow groove in the roller which supported the record-fillet of paper. In this man, ner the variable lines of the Vail alphabet were permanently indented in the paper with perfect facility and unerring regularity. Mr. F. B. Read in his biographical sketch of Samuel F. B. Morse (in the work just quoted), after alluding to his original apparatus as being placed by him "in Mr. Vail's hands for an entire mechanical reconstruction throughout, to speak a language not only wholly unknown to the first machine, but to perform entirely new functions, and to produce an entirely new system of signs and letters which the first by its structure was physically incapable of being made to speak;" adds with regard to Mr. Vail's subsequent improvement, "His more perfect invention of a steel style upon a lever which could strike into the paper as it was drawn onward over a grooved roller and *emboss* upon it the same alphabetic characters, was not made until 1844, about the time the first line of telegraph began to operate between Baltimore and Washington."†

Simple as may appear the substitution of the dry point for the inked wheel or pen, its introduction effected a wonderful saving of time, of attention, and of annoyance. In a memorandum attached to the original model of the lever-style and grooved roller, Alfred Vail wrote, "I have not asserted publicly my right as first and sole inventor, because I wished to preserve the peaceful unity of the invention, and because I could not according to my contract with Professor Morse, have got a patent for it."‡

Mr. Read, in the same biography of Morse, after quoting his feeble and insufficient tribute to Vail, in his speech at the banquet given at New York on the evening of December 29, 1868, in honor of the "successful" inventor, (in which he said of his intellectual offspring, "It found a friend in Mr. Alfred Vail, of New Jersey, who with his father and brother *furnished the means* to give the child a decent dress;") makes the comment, "It would have been more magnanimous if in those last days of the aged savant he had stated the precise facts, and given Alfred Vail the full credit to which he was justly entitled. He would thus have generously raised a fitting monument to the memory of one who had years before 'been gathered to his fathers' in the prime of manhood, who had with wondrous modesty and singular reticence refrained from claiming as of his own invention, the improved 'Morse' instrument and alphabet." §

In again referring to this subject in his following sketch of the life of Vail, the author adds, "These are the quiet and subdued terms in which Professor Morse was content to hand his co-inventor and early friend down to posterity. He makes no allusion to Alfred Vail which would lead any one to suspect that he was anything more than a skillful mechanic;—that Vail had ever done anything beyond putting into form the conception of Morse's brain. To say the least, it was an unhappy holding off from a magnanimous and generous course."‖

*A collection of biographical notices, entitled *Up the Heights of Fame and Fortune*, by F. B. Read, 8vo. Cincinnati, 1873, pp. 270, 271. Thirty-four pages are devoted to an account of the life of Alfred Vail; who died at Morristown, January 18, 1859.

† *Up the Heights of Fame and Fortune*, pp. 244, 245.

‡ Quoted in same work: p. 291.

§ Same work: p. 244.

‖ Same work: p. 297. A friend of Mr. Vail, (unnamed,) who visited Professor Morse at his request during his last illness in March, 1872, is reported as stating, "In

At a meeting of the Directors of the "Magnetic Telegraph Company" held at Philadelphia on the 16th of February, 1859, for the purpose of giving expression to their feelings on the recent death of Alfred Vail (a brother Director), Amos Kendall in seconding and warmly supporting the offered resolutions of respect and grief, is thus reported: "In the words of the distinguished associate and friend of both, the Hon. Amos Kendall, 'If justice be done, the name of Alfred Vail will forever stand associated with that of Samuel F. B. Morse, in the history of the invention and introduction into public use, of the Electro-magnetic Telegraph. . . . Mr. Vail was one of the most honest and scrupulously conscientious men with whom it has ever been my fortune to meet.'"*

Surely it is time that Alfred Vail should receive the tardy justice of some public acknowledgment of his very ingenious and meritorious inventions in telegraphy, and of grateful remembrance particularly for his valuable contribution to the "Morse system" of its practically most important element.

NOTE H. (From p. 317.)

AN UNWARRANTED ARRAIGNMENT.

Henry, elected December 3, 1846, to the position of "Secretary" and Director of the Smithsonian Institution, was for ten years engaged in a difficult but resolute struggle to impress upon its administration his own sagacious and far-sighted policy; at that time but little appreciated by the vast majority of those who wielded political or literary influence. It was during the latter portion of this critical period, while still almost entirely abstracted from his favorite pursuits, that he was made the subject of a most wanton, unprovoked, and unlooked-for aspersion. In this ill-advised attack—elaborately prepared either by or for Professor Morse, more than a year before its wide-spread publication,† the pamphleteer not only boldly assailed the scientific reputation of the great experimental physicist, but ventured (for the first time in the latter's career) to impugn his *truthfulness*, in an important testimony given in certain telegraph suits, some half a dozen years previously, in reluctant obedience to legal summons.‡ This testimony thus exacted, of course failed to sustain the complainant's exorbitant claims to all possible forms of the electro-magnetic telegraph, and correspondingly failed to satisfy the cupidity of the actual prosecutors; and in this remarkable accusation, first published in 1855, could readily be discerned the mercenary inspiration of interested capitalists and assignees—anxious only to stretch the monopoly to its extremest grasp. To Professor Morse himself, in his early efforts, Henry had generously rendered every encouragement and assistance; and in

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a conversation of two hours, he several times said, 'The one thing I want to do now, is justice to Mr. Vail.' . . . Just four weeks from that day, he passed from earth; and I have never heard that he left one word for it. Indeed, I did not expect that he would." To this statement, Mr. Read adds, "Here we leave Professor Morse and his relations to Alfred Vail. Our only purpose has been simply to bring the facts concerning this wonderful invention, to the light of day. (Same page of the work: — p. 297.)

* Same work: p. 296.

† Professor Morse's signature upon the last page of the Impeachment (p. 96), is dated December, 1853. The pamphlet was published January, 1855.

‡ The Hon. S. P. Chase, while Governor of Ohio, (subsequently Chief Justice of the Supreme Court of the United States,) in a letter to Henry, dated Columbus, November 26, 1856, after reciting his professional connection with the litigations of 1849, says: "I remember very well that you were unwilling to be involved in the controversy even as a witness, and that you only submitted to be examined in compliance with the requirements of law. Not one of your statements was volunteered; they were all called out by questions propounded either verbally or in writing. . . . You could not have refused to respond to the questions propounded without subjecting yourself to judicial animadversion and constraint. Nothing in what you testified, or your manner of testifying, suggested to me the idea that you were animated by any desire to arrogate undue merit to yourself, or to detract from the just claims of Professor Morse."

his later successes had as freely extended his congratulations and his testimonials of the practical merits of his invention.*

To descend to a personal controversy with Mr. Morse, was utterly repugnant to Henry's feelings; to permit his serious impeachment to stand untraversed, appeared scarcely less objectionable. With a calm and self-respecting dignity, Henry simply presented the published arraignment to the Board of Regents, for their consideration and action, with a communication dated March 16, 1857, in the following terms:

"GENTLEMEN: In the discharge of the important and responsible duties which devolve upon me as Secretary of the Smithsonian Institution, I have found myself exposed, like other men in public positions, to unprovoked attack and injurious misrepresentation. Many instances of this it may be remembered occurred about two years ago, during the discussions relative to the organic policy of the Institution; but though very unjust, they were suffered to pass unnoticed, and generally made I presume no lasting impression on the public mind. During the same controversy however there was one attack made upon me of such a nature, so elaborately prepared and widely circulated by my opponents, that though I have not yet publicly noticed it, I have from the first thought it my duty not to allow it to go unanswered. I allude to an article from the pen of Prof. S. F. B. Morse, the celebrated inventor of the American electro-magnetic telegraph. In this, not my scientific reputation merely, but my moral character was pointedly assailed; indeed, nothing less was attempted than to prove that in the testimony which I had given in a case where I was at most but a reluctant witness, I had consciously and willfully deviated from the truth, and this too from unworthy and dishonorable motives.

"Such a charge, coming from such a quarter, appeared to me then, as it appears now, of too grave a character and too serious a consequence to be withheld from the notice of the Board of Regents. I therefore presented the matter unofficially to the Chancellor of the Institution, Chief Justice Taney, and was advised by him to allow the matter to rest until the then existing excitement with respect to the organization of the Institution should subside; . . . and I now embrace the first opportunity of bringing the subject officially to your notice, and asking from you an investigation into the justice of the charges alleged against me. And this I do most earnestly, with the desire that when we shall all have passed from this stage of being, no imputation of having attempted to evade in silence so grave a charge shall rest on *me*,—nor on *you*, of having continued to devolve upon me duties of the highest responsibility, after that was known to some of you individually, which if true should render me entirely unworthy of your confidence. Duty to the Board of Regents, as well as regard to my own memory, to my family, and to the truth of history, demands that I should lay this matter before you, and place in your hands the documents necessary to establish the veracity of my testimony so falsely impeached, and the integrity of my motives so wantonly assailed."†

A select committee of the Board of Regents having accordingly been appointed to examine fully into the imputations referred to, and thereupon to report the conclusion reached,—after a careful consideration of all the evidence and documents accessible, presented through its chairman, President Felton, of Harvard University, a comprehensive report, from which the following extracts are made:

"The committee have carefully examined the documents relating to the subject, and especially the article to which the communication of Professor Henry refers. This article occupies over ninety pages, and purports to be 'a defense against the injurious

* "It was my wish in every statement to render Mr. Morse full and scrupulous justice. While I was constrained therefore to state that he had made no discoveries in science, I distinctly declared that he was entitled to the merit of combining and applying the discoveries of others in the invention of the best practical form of the magnetic telegraph. My testimony tended to establish the fact that though not entitled to the exclusive use of the electro-magnet for telegraphic purposes, he was entitled to his particular machine, register, alphabet, &c. This however did not meet the full requirements of Mr. Morse's comprehensive claim."

† *Smithsonian Report* for 1857, pp. 85, 86.

deductions drawn from the deposition of Prof. Joseph Henry (in the several telegraph suits), with a critical review of said deposition, and an examination of Professor Henry's alleged discoveries bearing upon the electro-magnetic telegraph.' The first thing which strikes the reader of this article is, that its title is a misnomer. It is simply an assault upon Professor Henry; an attempt to disparage his character; to deprive him of his honors as a scientific discoverer; to impeach his credibility as a witness, and his integrity as a man. It is a disingenuous piece of sophistical argument, such as an unscrupulous advocate might employ to pervert the truth, misrepresent the facts, and misinterpret the language in which the facts belonging to the other side of the case are stated.

"Mr. Morse charges that the deposition of Professor Henry 'contains imputations against his (Morse's) personal character,' which it does not, and assumes it as a duty 'to expose the utter non-reliability of Professor Henry's testimony;' that testimony being supported by the most competent authorities, and by the history of scientific discovery. He asserts that he 'is not indebted to him [Professor Henry] for any discovery in science bearing on the telegraph,' he having himself acknowledged such indebtedness in the most unequivocal manner, and the fact being independently substantiated by the testimony of Sears C. Walker, and the statement of Mr. Morse's own associate, Dr. L. D. Gale. Mr. Morse further maintains that all discoveries bearing upon the telegraph were made not by Professor Henry, but by others, and prior to any experiments of Professor Henry in the science of electro-magnetism; contradicting in this proposition the facts in the history of scientific discovery perfectly established and recognized throughout the scientific world.

"The essence of the charges against Professor Henry is, that he gave false testimony in his deposition in the telegraph cases, and that he has claimed the credit of discoveries in the sciences bearing upon the electro-magnetic telegraph which were made by previous investigators; in other words, that he has falsely claimed what does not belong to him, but *does* belong to others. . . . Your committee do not conceive it to be necessary to follow Mr. Morse through all the details of his elaborate attack. Fortunately, a plain statement of a few leading facts will be sufficient to place the essential points of the case in a clear light." . . .

[After a review of the evidences furnished (unnecessary to be here reproduced), the report proceeds:]

"It thus appears, both from Mr. Morse's own admission down to 1848, and from the testimony of others most familiar with the facts, that Professor Henry discovered the law, or 'principle,' as Mr. Morse designates it, which was necessary to make the practical working of the electro-magnetic telegraph at considerable distances possible; that Mr. Morse was first informed of this discovery by Dr. Gale; that he availed himself of it at once, and that it never occurred to Mr. Morse to deny this fact until after 1848. He had steadily and fully acknowledged the merits and genius of Mr. Henry, as the discoverer of facts and laws in science of the highest importance in the success of his long-cherished invention of a magnetic telegraph. Mr. Henry was the discoverer of a principle, Mr. Morse was the inventor of a machine, the object of which was to record characters at a distance, to convey intelligence; in other words to carry into execution the idea of an electric telegraph. But there were obstacles in the way which he could not overcome until he learned the discoveries of Professor Henry, and applied them to his machine. These facts are undeniable. They constitute a part of the history of science and invention. They were true in 1848, they were equally true in 1855, when Professor Morse's article was published. . . .

"What changed Mr. Morse's opinion of Professor Henry, not only as a scientific investigator, but as a man of integrity, after the admissions of his indebtedness to his researches, and the oft-repeated expressions of warm personal regard? It appears that Mr. Morse was involved in a number of lawsuits, growing out of contested claims to the right of using electricity for telegraphic purposes. The circumstances under which Professor Henry, as a well-known investigator in this department of physics, was summoned by one of the parties to testify have already been stated. The testimony of Mr. Henry, while supporting the claims of Mr. Morse as the inventor of an admirable invention, denied to him the additional merit of being a discoverer of new facts or laws of nature, and to this extent perhaps was considered unfavorable to some part of the claim of Mr. Morse to an *exclusive* right to employ the electro-magnet for telegraphic purposes. Professor Henry's deposition consists of a series of answers to verbal, as well as written, interrogatories propounded to him, which were not limited to his published writings, or the subject of electricity, but extended to investigations and discoveries in general having a bearing upon the electric telegraph. He gave his testimony at a distance from his notes and manuscripts, and it would not have been surprising if inaccuracies had occurred in some parts of his statement; but all the material points in it are sustained by independent testimony, and that portion which relates directly to Mr. Morse agrees entirely with the statement of his own assistant, Dr. Gale. Had his deposition been objectionable, it ought to have been impeached before the court; but this was not attempted; and the following tribute to Professor Henry by the judge, in delivering the opinion of the Supreme Court of the United States, indicates the impression made upon the court itself by all the testimony in the case: 'It is due to him to say that no one has contributed more to enlarge the knowledge of electro-magnetism, and to lay the foundations of the great inventions of which we are speaking, than the Professor himself.'"

The committee, in summing up the various testimonies, justly declare of Professor Henry, that "he has freely communicated information to those who have sought it from him, among whom has been Mr. Morse himself, as appears by his own acknowledgments. But he has never applied his scientific discoveries to practical ends for his own pecuniary benefit. It was natural therefore that he should feel a repngnance to taking any part in the litigation between rival inventors, and it was inevitable that when forced to give his testimony, he should distinctly point out what was so clear in his own mind and is so fundamental a fact in the history of human progress, the distinctive functions of the discoverer, and the inventor who applies discoveries to practical purposes in the business of life.

"Mr. Henry has always done full justice to the invention of Mr. Morse. While he could not sanction the claim of Mr. Morse to the *exclusive* use of the electro-magnet, he has given him full credit for the mechanical contrivances adapted to the application of his invention. . . .

"Your committee come unhesitatingly to the conclusion that Mr. Morse has failed to substantiate any one of the charges he has made against Professor Henry, although the burden of proof lay upon him; and that all the evidence, including the unbiased admissions of Mr. Morse himself, is on the other side. Mr. Morse's charges not only remain unproved, but they are positively disproved.

"Your committee recommend the adoption of the following resolutions:

"*Resolved*, That Professor Morse has not succeeded in refuting the statements of Professor Henry in the deposition given by the latter in 1849, that he has not proved any one of the accusations against Professor Henry, and that he has not disproved any one of his own admissions in regard to Professor Henry's discoveries in electro-magnetism, and their importance to his own invention of the electro-magnetic telegraph.

"*Resolved*, That there is nothing in Professor Morse's article that diminishes in the least, the confidence of this Board in the integrity of Professor Henry, or in the value of those great discoveries which have placed his name among those of the most distinguished cultivators of science, and have done so much to exalt the scientific reputation of the country.

"*Resolved*, That this report, with the resolutions, be recorded in the Proceedings of the Board of Regents of the Institution."

The report was accepted, and the resolutions were unanimously adopted by the Board of Regents.*

* *Smithsonian Report* for 1857, pp. 88–98.

NOTE I. (From p. 319.)

OVERSTATEMENT OF MORSE'S INVENTION.

It was perhaps to have been expected that the owners of the Morse patents, knowing the influence which the unbiased opinions of Henry (subpœnaed as an expert) undoubtedly exercised upon the minds and decisions of the justices before whom the telegraph suits were brought for trial, should regard with much stronger feeling what seemed to them *adverse* in his testimony, than what was really favorable to their interests. But that the sweeping assumptions advanced by the claimants were unwarrantable, has been distinctly affirmed by the highest judicial authority.

Justice Woodbury, presiding at the United States Circuit Court (Massachusetts), in his decision in 1850, in the case of "Smith *vs.* Downing and others," remarked of the successive reissues of the original Morse patent, with expanding claims: "In his last renewal of 1848 there are introduced for the first time some changes of language, and some tendencies in a part of them (as well as in some of the arguments) to make the claim broader, and as in the letter just quoted, to cover all applications of electro-magnetism, if not of electricity, to convey intelligence, or to telegraph to a distance. . . . As this broader claim goes far beyond what we have already seen was that made in the caveat and in the first specification and in the original patent, as well as in all the subsequent renewals; as it conflicts with much of the language of this very last renewal, looking only to a new method and a mere improvement on what existed before; and as he seems to disavow it in his own evidence; and as on everything in the case, it is at least questionable whether he could have intended to patent anything except an improvement on what before existed, I do not think it just to place a broader construction on his language than the whole subject-matter and description and nature of the case seem to indicate as designed. . . . And I the more readily adopt this course for his own protection, as such broader view might subject his patent to be considered void, both for claiming too much, and for claiming also the invention of a mere principle. It would be claiming too much, as it would cover the application in every way—of electro-magnetism to telegraphs; when this as will be seen hereafter by the history of this subject, and as is sworn to by a large number of highly intelligent experts, had been known publicly and for years before Morse's first attention to the subject in 1832. Indeed he himself virtually admits the truth of this in his testimony. Others no less than the persons cited, as well as the history of the progress on this subject, show that several had before Morse not only made this discovery, but applied both electricity and electro-magnetism to the purpose of telegraphing. But if by his alphabet and record, he has been successful in making an improvement in the use of electricity for that purpose, and wished to secure the new method of doing it, he was at liberty in point of law to make out a patent for that new mode; but for nothing more. He came into the world too late for truly claiming much as new. A large galaxy of discoverers on this subject had preceded him."

To a similar purport was the language of Chief Justice Taney of the Supreme Court of the United States in his final decision in the case of "O'Reilly and others *vs.* Morse and others;" which however went so far as to condemn as untenable the substance of the eighth claim introduced by Morse's reissued patent of 1848. The Chief Justice said: "It is impossible to misunderstand the extent of this claim. He claims the exclusive right to every improvement, when the motive power is the electric or galvanic current, and the result is the marking or printing intelligible characters signs or letters at a distance. . . . The patent confers on him the exclusive right to use the means he specifies to produce the result or effect he describes,—and nothing more. . . . Indeed, if the eighth claim of the patentee can be maintained, there was no necessity for any specification further than to say that he had discovered that by using the motive power of electro-magnetism he could print intelligible characters at a distance. We presume that it will be admitted on all hands, that no patent could have issued on such a specification."*

Howard's Reports, vol. xv, pp. 112–119.

NOTE J. (From p. 319.)

HENRY'S APPRECIATION OF PROFESSOR MORSE.

Although Henry (together with several other eminent physicists and electricians,) was summoned by the contestants of Professor Morse's patent, his testimony tended probably quite as much to sustain what appeared to him the patentee's equitable claims, as to restrain his overshadowing pretensions. That both before and after these legal controversies, Henry cherished only kindly feelings toward Professor Morse, the following correspondence will sufficiently attest.

At the close of October, 1837, Henry had learned from Professor Gale, with a naturally warm interest, of his success in operating the Morse recorder by a proper adjustment of the length of coil on his Henry magnet, and a battery of 87 cells (each having about 14 square inches of zinc surface), through the length of five miles of cotton-wrapped copper wire (one-sixteenth of an inch in diameter), coiled on a large reel.* And on the 13th of November following, he was informed of his further success in interposing a second similar reel of wire (making ten miles) in the circuit, with but little diminution of effect.

In the following year, 1838, Henry, during his elaborate and profound researches on electrical "induction" (since become classical), desired to borrow one of these five-mile reels of wire, for the purpose of pressing his inquiries to their furthest extent. Professor Morse being then absent in Europe, his colleague Professor Gale very cheerfully lent the wire. On returning the borrowed wire in 1839, Henry, in acknowledgment of the courtesy, sent both to Professor Gale and to Professor Morse a copy of his memoir (read before the American Philosophical Society, November 2, 1838), "with the respects of the author."

Professor Morse, on his return, addressed a letter to Henry, dated New York, April 24, 1839, in which he said:

"MY DEAR SIR: On my return a few days since from Europe, I found directed to me, through your politeness, a copy of your valuable "Contributions," for which I beg you to accept my warmest thanks. . . .

"I was glad to learn, by a letter received in Paris from Dr. Gale, that a spool of five miles of my wire was loaned to you, and I perceive that you have already made some interesting experiments with it. In the absence of Dr. Gale, who has gone South, I feel a great desire to consult some scientific gentleman on points of importance bearing on my telegraph. I should be exceedingly happy to see you, and am tempted to break away from my absorbing engagements here to find you at Princeton. In case I should be able to visit Princeton for a few days, a week or two hence, how should I find you engaged? . . . I have many questions to ask, but should be happy in your reply to this letter of an answer to this general one: Have you met with any facts in your experiments thus far that would lead you to think that my mode of telegraphic communication will prove impracticable? . . . I think that you have pursued an original course of experiment, and discovered facts of more value to me than any that have been published abroad. I will not trouble you at this time with my questions until I know your engagements. Accompanying this is a copy of a report made by the Academy of Industry, of Paris, on my Telegraph, which I beg you to accept.

"Believe me dear sir,

"With the highest respect,

"Your most obedient servant,

"SAMUEL F. B. MORSE."

* This coil of wire, wound on a small axis of iron, formed a solid cylinder eighteen inches long and thirteen inches in diameter. Professor Gale's preparation for this experiment was noticed in Silliman's *Am. Journal of Science* (October, 1837, vol. xxxiii, p. 187). And Professor Morse, in a letter to Mr. A. Vail, dated October 7, 1837, congratulated himself that "Professor Gale's services will be invaluable to us, and I am glad that he is disposed to enter into the matter with zeal."

To this letter Henry replied as follows:

PRINCETON, May 6, 1839.

DEAR SIR: Your favor of the 24th ultimo came to Princeton during my absence, which will account for the long delay of my answer. I am pleased to learn that you fully sanction the loan which I obtained from Dr. Gale of your wire; and I shall be happy if any of the results are found to have a practical bearing on the electrical telegraph. It will give me much pleasure to see you in Princeton after this week; my engagements will not then interfere with our communications on the subject of electricity. I am acquainted with no fact which would lead me to suppose that the project of the electro-magnetic telegraph is impracticable; on the contrary, I believe that science is now ripe for the application, and that there are no difficulties in the way, but such as ingenuity and enterprise may obviate. But what form of the apparatus, or what application of the power, will prove best, can I believe be only determined by careful experiment. I can say however that so far as I am acquainted with the minutiæ of your plan, I see no practical difficulty in the way of its application for comparatively short distances; * but if the length of the wire between the stations be great, I think that some other modification will be found necessary in order to develop a sufficient power at the farther end of the line.† I shall however be happy to converse freely with you on these points when we meet. In the meantime, I remain,

"With much respect,

"Yours, &c.,

"JOSEPH HENRY."

A short time after this, Professor Morse visited Henry at Princeton; and during this first personal interview in May, 1839, received satisfactory answers to various questions presented. Among them, Henry stated that he had no reason to doubt that magnetism could be induced in soft iron "at the distance of a hundred miles or more by a single impulse or from a single battery:" (a striking expression of faith in his own "intensity" magnet:) also, that with a given battery, circuit, and electro-magnet at a distance, the inclusion of intermediate electro-magnets at way-stations would not sensibly reduce the magnetic power at the several points. On the subject of the differences between "quantity" and "intensity" magnets, Professor Morse was still greatly in the dark, and he asked the question, "Is it quantity or intensity which has most effect in inducing magnetism in soft iron?" Henry fully explained to him that for producing the greatest magnetic effects, a "quantity" magnet and battery, with short and free circuit, were required; but that for a long circuit (required for magnetizing at a distance), an "intensity" magnet and battery were indispensable.‡

* [It must be borne in mind that this was a year and a half after the writer had been informed by Dr. Gale of his successful experiment through ten miles of wire. By "comparatively *short* distances," therefore, he must evidently have intended distances less than those separating our principal cities.]

† [The peculiar form of expression here used, suggesting the probable occasion for another modification "in order to *develop a sufficient power—at the farther end of the line*," points directly to his own contrivance (exhibited before his classes, four years previously) of a supplemental "quantity" magnet and battery at the distant station. Henry had no doubt of being able to magnetize iron at a distance of several hundred miles, and hence evidently did not contemplate dividing the line into a "relay" of circuits, as devised by Professor Morse. His language that a re-enforcement may be necessary "*if the length of the wire* between the stations be great," plainly shows this. But he anticipated that the attractive power developed would be feeble; while he declared his confidence that there were no *scientific* "difficulties in the way." Surprise has been expressed that Henry did not frankly give Professor Morse the benefit of this solution of the suggested difficulty, if it were then in his mind. But is not the subsequent reticence of Professor Morse, on the expedient of a "relay" (invented by him two years previously, as alleged), much more surprising? Henry referred to the enfeeblement on a long line, as a merely "practical difficulty" easily "obviated by ingenuity."]

‡ Of the communications made on the occasion of this very interesting and important interview, occupying an "afternoon and evening," we have unfortunately only the result furnished by Professor Morse's very meager statement. (Prime's *Life of Morse*, chap. x, p. 422.) That Henry, in explaining the differing functions of the two

During the long and weary interval in which Professor Morse—with hope deferred—was unavailingly prosecuting his memorial to Congress for assistance, Henry wrote to him the following encouraging and friendly letter:

"PRINCETON COLLEGE, February 24, 1842.

"MY DEAR SIR: I am pleased to learn that you have again petitioned Congress in reference to your telegraph, and I most sincerely hope you will succeed in convincing our representatives of the importance of the invention. In this you may perhaps find some difficulty; since in the minds of many, the electro-magnetic telegraph is associated with the various chimerical projects constantly presented to the public, and particularly with the schemes so popular a year or two ago, for the application of electricity as a moving power in the arts. The case is however entirely different in regard to the electro-magnetic telegraph. Science is now fully ripe for this application, and I have not the least doubt, if proper means be afforded, of the perfect success of the invention. The idea of transmitting intelligence to a distance by means of electrical action has been suggested by various persons from the time of Franklin to the present; but until within the last few years, or since the principal discoveries in electro-magnetism, all attempts to reduce it to practice were necessarily unsuccessful. The mere suggestion however of a scheme of this kind, is a matter for which little credit can be claimed, since it is one which would naturally arise in the mind of almost any person familiar with the phenomena of electricity; but the bringing it forward at the proper moment, when the developments of science are able to furnish the means of certain success, and the devising a plan for carrying it into practical operation, are the grounds of a just claim to scientific reputation as well as to public patronage. About the same time with yourself, Professor Wheatstone, of London, and Dr. Steinheil, of Germany, proposed plans of the electro-magnetic telegraph; but these differ as much from yours as the nature of the common principle would well permit: and unless some essential improvements have lately been made in these European plans, I should prefer the one invented by yourself.

"With my best wishes for your success, I remain, with much esteem,

"Yours truly,

"JOSEPH HENRY."

Professor Morse's biographer, in reproducing this letter, makes the comment: "This was the most encouraging communication Professor Morse received during the dark ages between 1839, and 1843." And he again notices it on a subsequent page: "In the summer of 1842, Professor Morse communicated to the Hon. W. W. Boardman, member of the House of Representatives in Congress, the encouraging letter from Professor Henry, of February 24, 1842."* And when on December 30, of 1842, the Hon. Charles G. Ferris, of New York, reported in the House of Representatives the bill authorizing the construction of the telegraph, this justly valued testimonial of Henry, accompanied Professor Morse's memorial. The Hon. Fernando Wood, of New York (a colleague of Mr. Ferris), in reviewing the history of that enactment some thirty years later, (on the occasion of the memorial proceedings at the Capitol in honor of Professor Morse,) did not forget to remark: "With this letter [from Professor Morse] was another to him from Prof. Joseph Henry, now of the Smithsonian Institution, and then of Princeton College, indorsing and sustaining the application. Professor Henry was deemed high authority on all scientific subjects generally, and especially upon this, to which he had devoted much attention, being himself a successful investigator in electro-magnetic science."† The bill of Mr. Ferris passed the House of Representatives,

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kinds of magnets, would have unfolded the utility of the "quantity" magnet as a terminal re-enforcement of a long "intensity" line, seems highly probable,—if not almost inevitable. If Professor Morse did not profit by it, or failed rightly to apprehend it, this may be explained by his possible preoccupation with the project of dividing a long line into a succession of "relays."

*Prime's *Life of Morse*, chap. x, pp. 423 and 433.

†*Memorial of F. S. B. Morse*, April 16, 1872, Washington, 1875, p. 79.

February 23, 1843; and the Morse appropriation was secured, by passing the Senate, March 3, 1843.

Very shortly after this successful issue, Prof. James C. Fisher, who in the absence of Dr. Gale had taken his place in assisting Professor Morse, wrote to Henry explaining the method proposed for insulating the wires and laying the line of conductors underground, and asking advice as to the best method of wrapping. To this communication Henry replied by letter dated—

"PRINCETON, April 17, 1843.

"DEAR SIR: A friend of mine in Trenton has a machine for winding wire of which he promised to give a description. I will write to you on the subject and send you a copy of his answer. The greatest practical difficulty you will have to contend with, I should think, will be the insulation of the wires. Twine is a partial conductor, and by making the surface sufficiently extended, lateral transmission will take place to some extent. The loss however on this account can only be determined by direct experiment with extended wire. It will probably increase with an increasing ratio; first on account of the greater surface of contact, and secondly because electricity of greater tension will be required to send the current through the longer wire. In order to diminish the number of points of contact, it might perhaps be well to wrap around each wire—besides its continuous covering, an extra strand of coarse twine, with the several turns at a distance from each other. . . ."

When Professor Morse, in August, 1843, received 160 miles of covered copper wire, designed to form two independent circuits, each of a double line of 40 miles in extent, to reach from Washington to Baltimore (one pair for the outgoing circuit and the other for the return circuit), he invited Henry and others to be present at a preliminary experiment in New York City, on the 8th of August, to test the capacity of electrical transmission. This very interesting trial with so unusual a length of conductor would for the first time decide the correctness of Henry's opinion that magnetization could be effected "at the distance of a hundred miles or more by a single impulse." This critical test—never before attempted, Henry was unfortunately prevented from witnessing, by reason of his professional duties. The experiment was eminently successful with a battery of 100 Grove elements; and the magnet was operative with even half that number. The following letter to Professor Morse expressed Henry's regrets at being compelled to miss such an opportunity:

"PRINCETON, August 22, 1843.

"MY DEAR SIR: I hope you will pardon me for not before acknowledging the receipt of your kind letters of invitation to attend your galvanic exhibition. My time has been so much occupied during the last three weeks with an extra course of lectures and our examination, and so little at my own disposal, that I was unable to say whether I could be in the city on the day you mentioned or not. I did hope however to get away, but the examination prevented. Dr. Torrey was also engaged, and could not leave. I do not know however that I could have done much in the way of original experiments in the course of a single day. I am not quick in the process of inventing experiments unless my mind is thoroughly aroused to the subject by several days' exclusive attention to the work, and then I am obliged to pause between each effort.* I have not been able since I last saw you to devise a satisfactory process for determining the velocity of *galvanic* electricity; and on reflection I did not think it worth the expense which would be incurred, to have a machine constructed for the mere repetition of the experiments of Wheatstone.

"I think it probable that I shall visit the city next week, as I shall be unemployed from this time until a week from next Monday. If there is any prospect of your

*[An indication of the logical care bestowed by Henry on his experimental work, and the key to his successes. He had little confidence in the profit of empirical or "hap-hazard" trials.]

repeating any of your experiments previous to that time, I will be with you on any day you may appoint.

"With much respect and esteem,

"Yours truly,

"JOSEPH HENRY."

The answer to this, or whether any further preliminary experiments were jointly performed on the 160 miles of wire, does not appear. As the line of wires between Washington and Baltimore was being laid, Henry, anxious to emphasize the importance of keeping the separate wires at some distance apart throughout their circuit, addressed to Professor Morse the following friendly letter on the subject:

"PRINCETON, January 24, 1844.

"MY DEAR SIR: I am anxious to hear from you in reference to the telegraph, and I have intended to write to you on the subject for a month past, but extra college duties have occupied all my thoughts and all my time since the beginning of the present term. During the last vacation I occupied myself as usual with my investigations in electricity, and among other results, I arrived at one which I think may have an important bearing on the success of the telegraph. It is this: while a current of electricity is passing through a wire, one part of the conductor is constantly *plus* to any other part which succeeds it, the difference in the degree of the electrical state constantly increasing as the distance of the two points is greater. The maximum difference is therefore at the two ends; and when the two extremities of long wires are brought into near approximation, there is a great tendency in the elecricity to cut across from the one to the other. This tendency is not due as has been supposed, merely to the great resistance of the long wire and the cross-cut offering a less resisting channel, but to the fact of the one part being positive and the other negative, and the consequent great attraction of the electricity in the one part for the unsaturated matter in the other. . . . On reading your letter on the subject of the telegraph in the newspapers, I was struck with the idea that you had probably met with the very difficulty my researches have led me to anticipate. If this is the case, and your insulation is not found sufficient, you have no cause to blame yourself, since the previous state of knowledge on the subject of electricity could not lead you to suspect such a condition of things.

"With much respect,

Yours truly,

"JOSEPH HENRY."

The danger apprehended by Henry was realized; and of the nine miles of quadruple conductors laid in the ground, Professor Gale had already discovered that the galvanic current could not be carried through a single mile; a result partly due to the injury done to the insulation of the wires at some points, in the process of enveloping them in a tube, and partly to the energetic induction from the "extra current" first discovered by Henry. In a couple of weeks, Professor Morse wrote to Henry as follows:

"BALTIMORE, February 7, 1844.

"MY DEAR SIR: You must think it strange that I have not answered your letter of the 24th ultimo before this; but I have this moment received it in passing through this place on my way to New York, which I trust will be a sufficient apology for my apparent neglect. I have read your letter with much interest, and it has determined me to make you a visit on my return from New York, which will be the beginning of the week, perhaps on Tuesday morning, the 13th instant. . . . I found the difficulty which you apprehend in the insulation of my wires; but this I will explain when I have the pleasure of seeing you.

"In the mean time, believe me, with sincere respect,

"Your most obedient servant,

"SAMUEL F. B. MORSE."

At his next interview with Henry on the 13th of February, 1844, (on his way *from* New York,) he was advised to suspend his wires through the air on poles, at a sufficient elevation to avoid injury from the recklessness of mischievous boys: as Henry feared that the risk of "cross-cut" on long lines, even with good insulation, was scarcely avoidable.* Henry also informed him that this plan had been successfully adopted by Gauss and Weber ten years previously.

Professor Morse, who had thought of this method before, but with much distrust, at once determined to carry it out, and early in the following month, March, made preparations for its execution. Two methods of suspension were suggested, the first plan (that of Mr. Vail), the gathering of the four wrapped or insulated wires together at their supports, requiring but a single insulator on each pole, to which Professor Morse was himself inclined as involving least cost; the second plan (that of Mr. Ezra Cornell), the scattering of the wires, and the supporting of them apart on independent insulators. The following is Professor Morse's account to Mr. Cornell of a second interview and consultation with Henry on this subject, on the 1st of March, 1844, (on his way *back to* New York,) which he inadvertently confounds with his preceding interview two or three weeks earlier:

"On my way to New York, where I went to order the fixtures, I stopped at Princeton, and called on my old friend Professor Henry, who inquired how I was getting along with my telegraph.† I explained to him the failure of the insulation in the pipes, and stated that I had decided to place the wires on poles in the air. He then inquired how I proposed to insulate the wires where they were attached to the poles. I showed him the model I had of Mr. Vail's plan; and he said: 'It will not do; you will meet the same difficulty you had in the pipes.' I then explained to him your plan, which he said would answer."‡ And this is the method since universally adopted in this country. On the 24th of May following, the first message was sent over the completed telegraph line by Professor Morse from Washington to Baltimore, and immediately repeated by Mr. Vail from Baltimore back to Washington.

The success of this new enterprise (foreseen, encouraged, and promoted, by Henry) having been assured, various competitors sprang up as usual, (with similar and with dissimilar systems,) to share in its benefits and profits; and in a few years numerous litigations arose in resistance of real or supposed infringements. Notwithstanding the zeal and bitterness infused into these controversies by interested partisans, Henry never lost his interest in the success of Professor Morse's plan of telegraphing; but while desirous that meritorious rival schemes (such as that of the printing telegraph, —first invented by Alfred Vail, in September, 1837, and developed by Royal E. House in 1846, to a practical operation) should have a fair trial, he steadily refused to be made a party to any such discussions; until at last he was summoned by *subpœna* to attend a trial at Boston, to testify to the pre-existing state of the art.§ In occupying

* "Mr. Morse visited me at Princeton to consult me on the arrangement of his conductors. During this visit we conversed freely on the subject of insulation and conduction of wires. I urged him to put his wires on poles." (*Smithsonian Report* for 1857, pp. 112, 113.

† [Such an inquiry would appear superfluous in view of Professor Morse's recent letter dated February 7. The whole coloring of the interview is inaccurate.]

‡ Prime's *Life of Morse*, chap. xi. pp. 479, 480. A treatise on the "Telegraph," just published, gives the following account of the plan adopted: "An arm thirty inches long, with a pin at each end, bearing a glass bureau-knob,—an insulation proposed by Mr. Cornell and approved by Professor Henry, was secured to the upper end of each pole. Around the bureau-knobs the conducting wires were wrapped." (*The Telegraph in America*. By James D. Reid. 8vo. New York, 1879, chap. xi, p. 116.)

§ "A series of controversies and law-suits having arisen between rival claimants for telegraphic patents, I was repeatedly appealed to to act as expert and witness in such cases. This I uniformly declined to do, not wishing to be in any manner involved in these litigations, but was finally compelled under legal process to return to Boston from Maine, (whither I had gone on a visit,) and to give evidence on the subject." (*Smithsonian Report* for 1857, p. 87.)

a position so distasteful to his sensitive and generous nature, it may well be supposed that however reserved and cautious his attitude, and whatever his preferences, the answers (necessarily conscientious) drawn from him by skillful attorneys defending the alleged infringements, and the coloring given to such answers in their elaborate arguments, would be little calculated to please the plaintiffs,—naturally intent on the broadest scope and comprehension of their claims. And from this time, Professor Morse, under the misjudging influence of interested supporters, seemed to forget that Henry had been among the most serviceable and unselfish of his many friends.

In 1854 Professor Morse's patent (of fourteen years from 1840) was about expiring, and an application for its extension for seven years longer, according to the provisions of the law, was pending before the Hon. Charles Mason,—one of the most able, conscientious, and indefatigable of Patent Office Commissioners. Inclined from the testimony he had examined, to believe that the merits of Professor Morse's invention had been greatly overestimated, and that his patent from the breadth of interpretation it had received, was acting to some extent as an obstruction to further progress in the art, he consulted with his friend, Professor Henry, as to the independent value of the Morse system, in view of the antecedent state of the art. Henry, with no other sentiment than that of impartial arbitrator, represented that Professor Morse, without the advantage of scientific culture, had the great merit of having combined and of having energetically developed and established a system of electro-magnetic telegraphy, in its method of signaling and of recording, the most efficient of contemporary methods. He referred to the needle-telegraph of his personal friend, Professor Wheatstone (whom he regarded as one of the most intelligent and ingenious of modern physicists), as being in his judgment inferior practically to the Morse telegraph; and he urged that care should be taken not to let the extravagant pretensions of Professor Morse's would-be friends lead to the opposite error of underrating an invention which was certainly of far greater value to the community, than any remuneration which had yet been reaped by its author from the short-lived monopoly.

The application of the patentee was granted by the Commissioner; and the patent was legally extended for seven years from the 19th of June, 1854. Professor Morse, in ignorance of this service, had at the time unfortunately written (or at least given his signature to) the ungracious and ungrateful assault on Henry, as a pretender in science, and a detractor of merit, when rising fame excited his envy. And early the following year, to the injury of himself alone, had the stricture published in a pamphlet, and widely distributed.

As a sufficient corrective of the strange misconception of his disposition and motives, Henry inquired of Judge Mason, if he recalled their interview on the question of extending the Morse patent; and the Commissioner of Patents responded in the following letter:

"UNITED STATES PATENT OFFICE, March 31, 1856.

"SIR: Agreeably to your request, I now make the following statement: Some two years since, when an application was made for an extension of Professor Morse's patent, I was for some time in doubt as to the propriety of making that extension. Under these circumstances I consulted with several persons, and among others with yourself, with a view particularly to ascertain the amount of invention fairly due to Professor Morse. The result of my inquiries was such as to induce me to grant the extension. I will further say that this was in accordance with your express recommendation, and that I was probably more influenced by this recommendation, and the information I obtained from you, than by any other circumstance, in coming to that conclusion.

"I am, sir,

"Yours very respectfully,

"CHARLES MASON."

"Prof. J. HENRY."

NOTE K. (From p. 322.)

THE DATE OF PROFESSOR MORSE'S "RELAY."

Although the depositions of Professor Morse, and of his principal assistant (given in law suits more than ten years after the event), assign from memory as the date of invention of the "relay" the spring of 1837, all the documentary evidence existing, points rather to the spring of 1838, as the date of its inception. First, we should expect at least a reference to this device in the article prepared for Silliman's Journal of Spetember, 1837, in announcing the intention of experimenting with "a circuit of several miles." Secondly, we should certainly expect to find it spoken of as a saving expedient in the caveat of October 3, 1837, if it were at that time in the author's mind, and he were desirous of protecting it. Thirdly, we should expect to find it unavoidably brought forward (at least as a suggestion) before the committee of the Franklin Institute, February 8, 1838, when the doubt was expressly discussed in the committee's report as to the practicable distance to which the telegraph could be made to signal. This conspiracy of silence, this conspicuous absence (in every published case) of the slightest hint upon the subject, although so directly prompted and invited, is difficult (*ex post facto*) to account for. The earliest documentary reference now extant, to a junction of circuits, occurs in the application for a patent signed by Professor Morse April 7, 1838.

On filing this application in the Patent Office, he had requested that it might be retained in the secret archives, unacted upon, until he should have procured his foreign patents. He left this country for Europe with that object May 16, 1838, and returned to New York April 15, 1839. For a year or more afterward he took no step toward procuring his patent, till he wrote the following letter to the "Hon. H. L. Ellsworth, Commissioner of Patents":

"NEW YORK, May 2, 1840.

"DEAR SIR: I have never received my patent papers from your office. I believe there was something to be done on my part in relation to a drawing for one of the duplicates, which I was prevented from accomplishing by the necessity of preparing suddenly for my visit to Europe with the telegraph. I have nearly completed an improved apparatus for which I intend to take out a patent, adding it to my patent already executed, as an improvement. . . .

"Your old friend and classmate,

"SAMUEL F. B. MORSE."

To this the Commissioner replied as follows:

"PATENT OFFICE, May 14, 1840.

"SIR: The specifications and drawings of your alleged improvement in the mode of communicating signals by the application of electro-magnetism are herewith returned to you, the explanatory reference in the same not being sufficient to properly illustrate the invention. Some annotations pointing out the parts where these are wanting are marked in pencil in the margin of the description.

"Your favor of the 2d instant has been received; in reply to which the office has to state that the delay attending the granting of your application has not been caused by any want of attention on its part. Some two years since, when your patent was about being issued, a request was made by you that the case might be postponed until you should have received letters patent from the European governments. This request was complied with, and as no communication has been received from you since in relation to the issuing of the patent, the case has been permitted to lie over. The patent will be issued however immediately on the return of the papers.

"Yours respectfully,

"H. L. ELLSWORTH."

The amended specification and a duplicate set of drawings were returned to the Patent Office by Professor Morse, with a letter dated New York, May 18, 1840. It was then discovered that the original oath of invention required by law was defective in omitting a specific date, the space for the day and the month having been left blank. The applicant having been informed of this by official letter dated May 26, 1840, a new affidavit, properly executed, was sent to the Patent Office May 29, 1840, and the patent was finally issued June 20, 1840.

Whether the true date of the invention of the "relay," by Professor Morse, be 1837, or 1838, is not regarded as a matter of any importance historically, as in either case, he is fully credited with its original conception.

NOTE L. (From p. 325.)

ALPHABETIC BINARY NOTATION.

It seems proper to take some notice of the growth of that beautiful invention, the bi-signal alphabet. Its origin appears to be considerably earlier than that of its congener, the binary arithmetical notation devised by Leibnitz two hundred years ago. An alphabetic code of signals is indeed as old as the time of the Greek historian Polybius (150 years before the Christian era), who describes in the tenth book of his General History a method of signaling to a distance any required dispatch by means of torches,—which he says was invented by Cleoxenus and Democlitus, and perfected by himself. In this scheme the Greek alphabet of 24 letters is distributed into five series or tablets, each comprising five letters: (the last space being vacant.) Then torches (from one to five) exposed on the left side, will indicate the group or tablet; and similar torches raised on the right side, will indicate the place of the letter on the tablet.* This system may obviously be very easily resolved into a bi-signal alphabet. It appears that the emperor Leo VI, (of the eastern division of the empire) about the year A. D. 900, in a chapter of his "Military Tactics," on naval warfare, described a plan somewhat similar to the above.†

An early English example of the bi-signal alphabet is to be found in Francis Bacon's "Advancement of Learning," published in 1605. In this Treatise, discoursing on cryptography, he observes: "We shall here annex a cipher of our own, that we devised at Paris in our youth. . . . The invention is this: let all the letters of the alphabet be resolved into two only, by repetition and transposition; for a transposition of two letters through five places or different arrangements, will denote two-and-thirty differences, and consequently fewer or four-and-twenty,—the number of letters in our alphabet." (It will be remembered that at this date the letters J and U had not been differentiated from I and V.) Bacon then gives an example of "a bi-literal alphabet" consisting of the permutations of "a" and "b" through five places; and he subjoins the comment that "this contrivance shows a method of expressing and signifying one's mind *to any distance*, by objects that are either visible or audible, provided the objects are capable of two differences, as bells, speaking-trumpets, fire-works, cannon, &c."‡

In the "Cyclopædia" of Doctor Abraham Rees, published early in the present century (1802-1819), under the word "cipher" are presented among a variety of interesting alphabetic notations, examples of one formed by the combinations of three characters, and of one formed by two characters; the latter evidently copied from Bacon. The compiler says: "Another mode of corresponding by cipher is striking two, or three bells of various sizes." After remarking that two symbols require a larger combination for each letter than three, and giving an example of each kind, the writer adds: "The effect will be the same, whether the writer make use of arithmetical characters, letters, dots, lines, mathematical diagrams, or any other sign which admits of two, or of three differences." Employing as an instance the figures 1 and 2, he makes use of five recurrences for each letter, as in the example given by Bacon, and he follows a

* Polybius's *History*; lib. x. cap. 45. Greek and Latin edition of A. F. Didot, Paris, 8vo. 1852. pp. 474, 475.

† "The emperor Leo VI, in his chapter on naval tactics (chap. xix), describes almost exactly Myer's army code, concluding with the remark, 'as the ancients did.'" (*Johnson's Universal Cyclopædia*; edited by Dr. Barnard: art. "Naval Signals," vol. iii. p. 734.)

‡ *On the Dignity and Advancement of Learning*, book vi, chap. i.—Bohn's edition, 1858, pp. 222, 223.

similar order of permutations. The two symbols—the single dot or period (.), and the double dot or colon (:),—are also employed for the same purpose. *

In the following table are displayed several examples of bi-signal alphabets, chronologically arranged. † In the first column, the two symbols "a" and "b," and in the second column the two symbols "1" and "2," may stand for dots, lines, colors, bells, or any other distinctions of sight or sound, as indicated by Bacon and by Rees. In the third column is exhibited the notation of an acoustic alphabet devised by Mr. James Swaim, of Philadelphia, and published in 1829, in a pamphlet entitled "The Mural Diagraph, or the Art of Conversing though a Wall." In this scheme (sometimes designated the *prison* alphabet), the symbol "t" signifies an audible tap or knock, and the "s" an audible scratch. ‡ In the next three columns, the two symbols "r" and "l" represent a movement of a galvanometer needle to the *right* and to the *left*. In the last three columns, the symbols "s" and "l" represent a short mark or dot, and a long mark or dash.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	Bacon.	Rees.	Swaim.	Schilling.	Gauss & Weber.	Steinheil.	Original Morse.	Later Morse.	European Morse.
	1605.	1809.	1829.	- - - -	1833.	1836.	1838.	1844.	1851.
A	aaaaa	11111	t	rl	r	lrl	sss	sl	sl
B	aaaab	11112	tt	rrr	ll	lrrl	ss ss	lsss	lsss
C	aaaba	11121	ttt	rll	rrr	llr	s ss	ss s	lsls
D	aaabb	11122	tttt	rrl	rrl	rl	sss s	lss	lss
E	aabaa	11211	s	r	l	l	s	s	s
F	aabab	11212	ss	rrrr	rlr	lrr	s sss	sls	ssls
G	aabba	11221	sss	llll	lrr	rrl	ss s	lls	lls
H	aabbb	11222	ssss	rlll	lll	rrrr	ssss	ssss	ssss
I	abaaa	12111	ts	rr	rr	r	sl	ss	ss
J	- - - -	12112	t tts	rrll	- - - -	r	ss s	lsls	slll
K	abaab	12122	t t	rrrl	rrr	llr	lsl	lsl	lsl
L	ababa	12211	t tt	lrrr	llr	rll	l′	l′	slss
M	ababb	12212	t ttt	lrl	lrl	rrr	lss	ll	ll
N	abbaa	12221	t tttt	lr	rll	rr	ls	ls	ls
O	abbab	12222	t s	rlr	rl	lll	ss	s s	lll
P	abbba	21111	t ss	llrr	rrrr	rllr	sssss	sssss	slls
Q	abbbb	21112	t sss	lllr	- - - -	- - - -	ssls	ssls	llsl
R	baaaa	21121	t ssss	lrr	rrrl	ll	s s	s ss	sls
S	baaab	21122	t ts	ll	rrlr	llrr	sls	sss	sss
T	baaba	21211	tt tts	l	rlrr	lr	lls	l	l
U	- - - -	21212	tt t	llr	lr	rlr	sll	ssl	ssl
V	baabb	21221	tt tt	lll	rlr	rlr	l	sssl	sssl
W	babaa	12121	tt ttt	rlrl	lrrr	rlrl	ssl	sll	sll
X	babab	22212	tt tttt	lrlr	- - - -	- - - -	ll	slss	lssl
Y	babba	22221	tt s	rllr	- - - -	- - - -	sl	ss ss	lsll
Z	babbb	22122	tt ss	rlrr	rrll	rrll	sls	sss s	llss

* Rees' *Cyclopædia*, vol. viii, art. "Cipher."

† Of two early alphabets for the electric telegraph,—that of Lomond in 1787, and that of Dyar in 1828, no records appear to exist. A plan was suggested by Henry at Albany in 1831 or 1832, for indicating letters on a bell by the number of their position in the alphabet: "a" by 1, "b" by 2, "c" by 3, &c. Thus the words "come back" would be represented by the following taps: 3-15-13-5—2-1-3-11; the word "electromagnet," by 5-12-5-3-20-18-15—13-1-7-14-5-20. The cipher or zero occurring at the 10th letter "j," and at the 20th letter "t" would be indicated by a rapid rattle of the bell. It does not appear however that this alphabet was actually employed, unless perhaps experimentally.

‡ *The Mural Diagraph*, etc. "Through the wall they are content | To whisper, at the which let no man wonder." Midsummer Night's Dream, v. i. By James Swaim. 16-mo. 24 pages. Philadelphia. Printed by Clark & Raser. 1829. pp. 13, 14. The signs were used numerically; and beyond "26" (the letters of the alphabet) were applied to a numbered vocabulary.

The *first* column in the above tabular view, represents the scheme proposed by Bacon, and designated by him "A Bi-literal Alphabet;" a scheme—as he points out, "practicable in all things that are capable of two differences." The advantage of representing every letter by five tokens, is that it dispenses with the necessity of spacing the letters from each other.

The *second* column represents an alphabet shown and described in Rees' "Cyclopædia" as already referred to. In this alphabet the first nine letters follow exactly the notation of Bacon. After the interpolated letter J, (which takes the symbol for K,) the remainder of the alphabet from K to V inclusive, follows regularly the notation of Bacon—shifted two letters downward. The only symbols differing from Bacon's, are those for X, Y, and Z.

The *third* column gives the alphabet of Swaim above mentioned. The author has not been successful in arranging for his letters the simplest combinations of taps and scratches which might have been selected; having given to N, R, T, and W, five signals, and to X, six; while four of his signs are sufficient to represent 30 different characters. Moreover by adopting a *numeral* system of designation, he has been driven to the awkward and entirely unnecessary expedient of introducing spaces into letters in seventeen cases, or in two-thirds of the alphabet; that is in all letters following the ninth letter—I.

The *fourth* column gives the alphabet of Schilling, as represented in Vail's "Electro-Magnetic Telegraph:" (page 156.) The date of this is uncertain; involving as it does the question when Schilling first employed a single circuit and a single galvanometer in his telegraphic arrangement. Whether he or Gauss and Weber first devised this very important simplification is equally undetermined; though the presumption is in favor of Schilling having been the first to introduce the bi-signal alphabet into telegraphy. With a judicious distribution of the simplest signs to the most frequent letters, the average number of elementary signals need not exceed two and a half for every letter used, (or just one-half the number required by Bacon's alphabet,) in any lengthy communication. Steinheil, who was very imperfectly acquainted with Schilling's labors, appears to regard his system as imitated from that of Gauss and Weber.*

The *fifth* column gives the alphabet of Gauss and Weber, as represented in Turnbull's "Electro-Magnetic Telegraph." † In this alphabet C and K have the same symbol; as have also F and V.

The *sixth* column gives the alphabet of Steinheil as represented in Dub's *Anwendung des Elektromagnetismus:* Berlin, 1863: (2d ed. 1873, sec. v, page 343:) in Vail's Treatise; (page 182:) and in Turnbull's Treatise; (1853, page 97.) In this alphabet C and K have the same character; I and J have the same; and U and V have the same; the letters Q, X, and Y, being dispensed with. Steinheil remarks of its arrangement, "The alphabet I have chosen represents the letters that occur the oftenest in German, by the simplest signs"; a plan also adopted by Schilling and by Gauss.

The *seventh* column gives the original alphabet of Morse, as devised by him (or by his assistant—Mr. Vail) in 1838; and for the first time described in his application for a patent dated April 7, 1838. This is accordingly the alphabet presented in Morse's first patent, dated June 20, 1840. In this, he has given the same symbol to G and J; the same to I and Y; and the same to S and Z. It must be borne in mind that down to the year 1838, Professor Morse had conceived only the naval system of signals by means of numbered words, and the method of recording such numbers by the alternating or continuous zig-zag mark, equivalent to the right and left deflections of Steinheil's register; ‡ and that not till some time in January of that year (1838), did he make the great advance of substituting the up and down movement of the armature recorder, for its transverse motion. He then for the first time made his telegraphic communi-

* Sturgeon's *Annals of Electricity*, etc. vol. iii, pp. 448, 450.

† Second edition, 1853, p. 60.

‡ New York *Journal of Commerce*, of September 7, 1837, and of January 29, 1838.

cations by means of an alphabet; and improving on his predecessors, devised this alphabet in its simplest form, of a rectilinear succession of dots and lines.

A few years later, the modification given in the *eighth* column was adopted;* being the code now in use in this country. This second alphabet of Morse retains but seven of the letters in his original alphabet; namely, E, H, K, L, N, P, and Q. The remaining symbols are changed in their application. Both of these alphabets present the anomaly of employing for the letter L the unique symbol, a dash of double length: a symbol whose combinations with dots might have been much more appropriately reserved for designating numerals. And they both also present the very awkward arrangement of introducing in five or six cases, a space in the middle of a letter. This occurred with B, C, D, F, G or J, and R, in the first alphabet, and remains with C, O, R, Y, and Z in the later alphabet. Whence it becomes difficult to distinguish between C and IE, between O and EE, between R and EI, between Y and II, and between Z and SE; and if on the other hand the intra-literal space be made too brief, C or R may easily be mistaken for S, O for I, and Y or Z for H.

The *ninth* and last column gives the alphabet adopted by the Vienna convention in October, 1851, for European languages; as represented in Prescott's larger treatise on *Electricity and the Electric Telegraph*, 1877: (page 480.) This alphabet avoids the obvious blunder in Morse's notation, and presents a homogeneous system. In this code eleven of the Morse letters are changed: C, F, L, and R, having been taken from Gerke's alphabet, O, and P, from Steinheil's, and J, Q, X, Y, and Z, from other sources. Of the *original* "Morse alphabet" only four letters are retained, viz, E, H, K, and N. This European or "international" alphabet is however in a few of its symbols, better adapted to the German than to the English language. Accordingly in the Atlantic cable alphabet, the two letters M (ll), and O (lll), have been transposed; as in English the letter O occurs nearly three times as frequently as the letter M.

We thus perceive by what apparently small steps so simple a contrivance as an alphabetic notation, (scarcely demanding the exercise of invention,) has been successively modified and improved. But although the "Vienna" alphabet is now universally employed elsewhere, American operators have not yet had the intelligent courage to incur the temporary additional labor and inconvenience of change, for the permanent advantage of a more perfect system.†

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* Represented in Vail's Treatise, 1845, p. 27; in Turnbull's Treatise, 1853, p. 73; in G. B. Prescott's *Hist. of Electric Telegraph*, 1860, p. 89; and in F. L. Pope's *Modern Practice of the Electric Telegraph*, 4th ed. 1871, p. 101.

† "It has been proposed to introduce the European alphabet in this country also; but although the advantages of such a reform would doubtless be numerous, yet it may perhaps be better to suffer some inconvenience from an acknowledged imperfection, than to attempt to remedy it by introducing a change that would for a time cause serious annoyance to the thousands of skillful operators now in the service." (Prescott's *Electricity and the Electric Telegraph*, 1877, chap. XXX, p. 431.)

THE EFFECT OF IRRITATION OF A POLARIZED NERVE—"PFLÜGER'S ELECTROTONUS."

By B. F. Lautenbach, M. D., Ph. D.,
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HISTORICAL RÉSUMÉ.

Ritter* observed, when he applied for a long time ($\frac{1}{2}$ hour) a strong galvanic battery to a nerve, that there resulted a continual decrease in the movements of the finger and the arm on the silver (*i. e.*, negative) side of the battery. In the same parts on the zinc (positive) side he observed a continual increase in the motor effects of the current. This effect lasted for a short time after the experiment was discontinued.

On carefully repeating this experiment, Ritter came to the result that the current developed by the battery inhibited the voluntary movements in the arm to which the negative electrode was applied, while the mobility of the other arm, to which the positive electrode was applied, was increased.

Du Bois Reymond† attributed these results to diminution and augmentation of the irritability of the nerves caused by the constant current; the augmented excitability being produced by the passage of an ascending current, while the diminished excitability was caused by a descending current.

In 1828–'30 Nobili‡ observed certain facts which bear more nearly on our present subject than those observed by either of the previous experimenters. This investigator found that frog preparations, which through accident had become tetanized, grow quiet when a current in a special, or possibly in any, direction, was passed through the nerve. In explanation, Nobili believed that the constant current places the nerve in such a state as to render impossible the receiving and conducting of the contraction-producing cause. Nobili, at the same time, recommended his discovery to physicians for the cure of tetanus.

Matteucci§ made some experiments on this subject, but these resulted in but little that was not previously known. With the exception that he proved that the relief afforded in tetanus by a constant current is but

* Beiträge zur näheren Kenntniss des Galvanismus, etc., Jena, 1802, B. ii.

† Unters. über thierische Electrici tät, B. i, p. 367.

‡ Analyse expér. et théor. des phén. phys. produits par l'électric. sur le grenouille, etc., Annales de chimie et phys., 1830, p. 91.

§ Essai sur les phén. électr. des animaux, Paris, 1840, 8, p. 29.

transitory and that currents travelling in both directions act paretically, his results were but confirmatory of those obtained by Nobili.

The first who really systematically investigated this subject was Valentin.* This investigator applied the constant electrodes to the ischiadicus, just at the entrance of this nerve into the gastrocnemius, while the irritating electrodes were applied at the point of exit of the nerve from the pelvis. Valentin found that when the constant current was passing through the nerve the irritating current gave a weaker contraction than when this was not the case, or, at times, none. This author also showed that the same diminution in the effect of the irritating current occurred when this was placed between the constant current and the muscle. This latter result, however, was produced in the experiments of Valentin only when the current was ascending, and not when a descending current was employed.

Eckhard† confirmed the observations of Nobili and Valentin. He found that an electrical irritation can be made to lose its effect when between it and the muscle a constant current is made to pass through a given portion of the nerve. Not only did he find this to be true for electrical but also for mechanical and chemical irritants. This inhibitory effect was manifest when the polarizing or constant current was made to pass in either an ascending or a descending direction, provided that this current was of a certain strength (5–6 large Daniel elements). This author also confirmed the statement of Valentin that when the irritation (mechanical, chemical, or electrical) is applied to the nerve above the point where this is being polarized the effect is no longer so constant.

In his first paper Eckhard made the statement, which he afterwards withdrew, that the "paretic" effect was most constant when an ascending polarizing current was used.

In a second paper‡ Eckhard irritated by means of an induced current, and measured the muscular contractions thereby produced by means of a Helmholtz myograph. His previous observations were confirmed. When the constant current was applied to the nerve above the irritation, ascending polarization only diminished the effect of the irritation, thus showing a diminished excitability of the nerve between the positive electrode and the muscle. When the descending current was employed a state of augmented excitability of the nerve was produced between the negative electrode and the muscle.

Pflüger,§ whose experiments and "laws" will frequently be referred to in this paper, was the next investigator who devoted his atttention to this field of research. He made use of weak currents, while the pre-

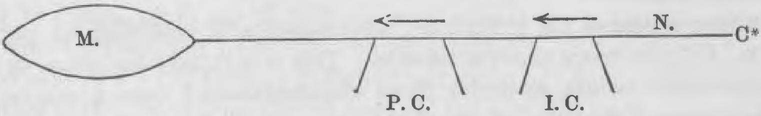
* Lehrb. der Phys. des Menschen, B. ii, Abth. 2, p. 155.

† Der galv. Strom als Hinderniss der Muskelzuckung. Zeitschr. für rat. Med., N. F., B. iii, p. 198.

‡ Ueb. den Einfl. des const. galv. Stromes auf die Erregbark. der motor. Nerven, Beiträge zur Anat. und Phys., H. 1, 1855, p. 25.

§ Allgem. Centralzeit., 1856, Nov. 22, 1857. Unters. über die Phys. des Elektrotonus, Berlin, 1859.

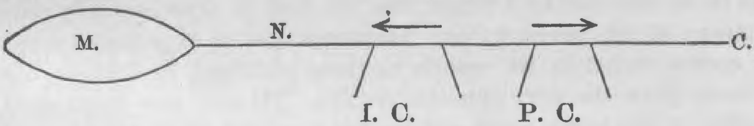
ceding investigators always employed strong currents. This author found that the ascending polarizing current did not under all conditions produce a diminution in the excitability of the nerve. The following are the results of this investigator:



"I. When a constant descending current is passed through the sciatic nerve near the gastrocnemius, and a descending irritating current is applied immediately above this, I found the irritation to give a smaller contraction when the constant current was passing through the nerve than when this was not the case."

Under these circumstances the muscular contractions were increased during the passage of the current.

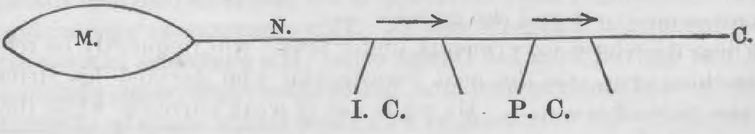
"II. The constant descending current passes through the nerve near the central end, a descending irritating current is applied to the nerve nearer the muscle. The irritations seem stronger when the constant current was absent."



The contractions produced by the irritation are stronger during the absence of the polarizing current.

"III. The constant ascending current passes through the nerve near the muscle, while the irritation was made at a more central portion. During the presence of the constant current the contractions are stronger than when it is absent."

"IV. The constant ascending current is applied to the nerve near the plexus, while the ascending irritating current is applied nearer the muscle. During the presence of the constant current the contractions are less strong than when this is removed."



Contractions less strong during the passage of the polarizing current.

In conclusion Pflüger sets up the theory that *the action of all irrita-*

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* In these diagrams, which are added by the author for the easier understanding of the views of Pflüger, M stands for the muscle, N for the nerve, and C for its central end; I. C. and P. C. stand for irritating and polarizing current. The arrows give the direction of the current.

tions which lie to the side of the negative pole (kathode) of a polarizing current is increased; while all irritations lying to the side of the positive pole (anode) have their action diminished.

When, however, this author used stronger currents he obtained the Eckhard results.

Pflüger repeated his irritations, alternately with and without polarization, sixty or more times a minute. This is certainly too often to obtain accurate results, as under these circumstances I have a number of times observed that the *effects* of the removal of the previous irritation overlap into the time of the succeeding irritation. His results were obtained on frogs taken in winter, spring, and summer, and in both varieties of the *Rana esculenta*, and in diseased as well as in healthy frogs.

When this investigator used polarizing currents of greater strength he obtained the results of Valentin and Eckhard. Both the irritations and the polarization were made by means of the albumen electrodes (*i. e.*, non-polarizable electrodes). To obtain the weakest possible currents which would produce muscular contractions, Pflüger made use of the rheochord. In some of his experiments the irritations were made by an interrupted current.

Schiff,* though in a number of experiments he obtained results similar to those obtained by Pflüger, was the first to *experimentally* criticise the theory of this investigator. He states that an experiment which at first corresponded in its results to those obtained by Pflüger, after a half hour gave the very opposite results. He also saw diminished excitability of the nerve produced by the constant current to the side of negative pole (katelectrotonus), and increased excitability occur to the side of the positive pole (anelectrotonus). In one experiment he saw augmented excitability of the nerve both above and below a descending polarizing current and diminished excitability above and below an ascending polarizing current.

Valentin,† in a later work on this subject, found, when very weak currents were employed, an increased excitability to occur to the side of the negative and also to the side of the positive pole of the polarizing current. These experiments were made with the nerve in *situ*, and consequently the non-polarizable electrodes had to be dispensed with.

Nor was Budge‡ more successful in his efforts to convince himself of the constancy of Pflüger's results. This experimenter's polarizing current was derived from 1–2 Daniel cells. His electrodes in some experiments were of amalgamated zinc, but in other experiments platinum and copper electrodes were used, as with these Budge states he obtained the same results as with the former. To test the excitability of the nerves this author resorted to a solution of ordinary salt as an irritant. He

* Lehrbuch der Nerven und Muskelphysiologie, 1859, p. 94.

† Valentin's paper I was never able to obtain, but was kindly informed of its contents by Professor Schiff.

‡ Virchow's Archiv., Bd. 18, p. 457.; Bd. 28, p. 398.

found that when a solution of salt, just strong enough to produce muscular twitchings, was applied above either a descending or ascending polarizing current, augmented contractions always occurred during the passage of the latter current. When, however, the salt solution was strong enough to produce tetanus, a polarizing current in either direction caused this to cease.

In another series of experiments the irritation was made by the closing of a constant current. When this irritating current was taken so weak as to produce only a trace of contraction in the muscle, the polarizing current on the contrary being very strong, the augmented excitability was only produced by a descending irritating current, and the contrary effect was produced by an ascending irritating current. When the polarizing current was of less strength and the irritating current stronger Pflüger's results were obtained.

Fick * used the induced current as an irritant. His results are as follows:

1. A descending irritating current applied to the nerve above an ascending polarizing current caused marked augmentation in the muscular contractions during the passage of the polarizing current.

2. An ascending irritating current applied to the nerve above an ascending polarizing current produced an unimportant augmentation in the muscular contractions during the passage of the latter current.

3. A descending irritating current applied to a nerve above a descending polarizing current produced marked diminution in the muscular contractions during the passage of the latter current.

4. An ascending irritating current applied to the nerve above a descending polarizing current produced not very marked diminution in the muscular contractions during the passage of the latter current.

From these results Fick concludes, against Pflüger, that, with moderately strong induced currents, the exciting impulse does originate in the region of the negative electrode, and that, with a very strong polarizing current the whole intrapolar portion of the nerve is put into a state of anelectrotonus.

In descending katelectrotonus Munk † found the excitability of the nerve increased for the descending and diminished for the ascending irritating current, but immediately after electronizing the nerve the reverse effect was obtained. In weak ascending anelectrotonus the muscular-contraction-exciting properties of the descending irritating current were increased, diminished for the ascending, while the opposite effect was obtained when the polarizing current was stronger. In weak ascending kate- and anelectrotonus the excitability was increased for currents traveling in the same direction. By polarization with stronger currents the excitability was increased for irritating currents traveling

* Beiträge zur Phys. des Elektrotonus, Vierteljahrschr. der Züricher Naturforsch. Gesellschaft, 1866, p. 48.

† Unters. zu allgem. Nervenphys. Arch. für Anat. und Phys., 1866, p. 369.

in either direction. For the intrapolar portion of the nerve the excitability was increased for irritating currents traveling in the same direction as the polarizing current, and decreased for currents traveling in the reverse direction, provided weak polarizing currents were employed. But when these currents were stronger the excitability of the nerve was decreased to irritating currents traveling in either direction.

Schiff and Herzen* publish a number of characteristic experiments which give results also widely differing from those obtained by Pflüger. These authors observed that if the polarizing current excites the nerve, after a lapse of time the opposite effect was obtained; and, *vice versa*, if the polarizing current "paretically" affected the nerve this could after a time be replaced by an augmentation of the excitability.

Notwithstanding so many of the best experimenters found it impossible to confirm the results of Pflüger, these results are now formulated in the books as *laws*. All other investigations are simply ignored and those of Pflüger adopted, it may be, because no other investigator has advanced a more beautiful theory which can be made to correspond to what is known of the electro-motor properties of the nerves. Even Wundt† was convinced of the truth of Pflüger's theory, though it appears that the results which he obtained by no means correspond with those of Pflüger, for on pages 34 and 35 of his "Untersuchungen" he speaks of an increased irritability between the anode and the muscle where an ascending current was used, which, according to Pflüger's theory (it demanding a diminished irritability under these circumstances), is an impossibility.

This was the state of the subject when early in September, 1876, Professor Schiff drew my attention to it, since which time I have constantly had it under consideration. The subject was so discouraging that I frequently felt like giving it up in disgust, but, urged on by Professor Schiff, I continued the study, and a definite explanation of the contradictory facts was arrived at late in December, 1876. Up to that time I had made almost two hundred successful experiments on the subject. The results then arrived at were presented in a preliminary communication in the February (1877) number of the *Archives de sciences phys. et naturelles*, as follows: "*The difference in the effect of an irritation of a polarized nerve, compared to that of a non-polarized nerve, does not solely depend on the circumstance that the portion irritated is to the side of the anode or to the side of the kathode, but much more on the proportion which exists between the strengths of the irritating and polarizing currents.*"

This conclusion my later experiments have abundantly confirmed, and in this paper it is designed not only to expose the results of these later experiments, but also to give *in extenso* the experiments which caused me to come to the foregoing conclusion. It may be thought that this is a

* Ueber die Veränder. der Erregbarkeit in dem dursch schwache constante Ströme polaris. Nerven, Moleschott's Untersuch., Bd. x, p. 432.

† I must here express my thankfulness for the kind assistance of M. Darier in a number of these experiments.

waste of "printer's ink," but when it is recollected that the Pflüger laws of electrotonus are universally adopted by electro-therapeutists, it will be seen that such an innovation as I propose to make in this branch of physiology must be substantiated by solid facts. As will be shown either in this work or in a paper to appear later, the facts here presented are not only of importance in this connection, but really derive their greatest importance from their affording us a long-sought-for means of explaining the symptoms produced by certain previously occult changes in the central nervous system.

THE EXPERIMENTS OF THE AUTHOR.

The method and apparatus employed.—The *irritations* were made by means of 1–4 small Daniel elements, the strength of which was reduced so as to produce a minimal contraction, by means of a rheochord comprising 3,199 centimetres of silver wire. A Valentin hammer or "key," introduced to make the connection of the current, was so placed as to always fall from the same height. This is absolutely necessary in all these experiments, as the height from which the hammer falls greatly influences the height or strength of the contractions by affecting the strength of the passing current.

The *polarizing current* was derived from 1–2 Daniel elements, and was also in connection with a smaller rheochord, 58 centimetres in length.

The *electrodes* employed for both polarization and irritation were Du Bois Reymond's "Zinc-clay non-polarizable electrodes," which, as Pflüger will no doubt concede, are less objectionable than the albumen electrodes which he employed.

The frog preparations and the electrodes were brought into a *moist-chamber*, where all the irritations were made.

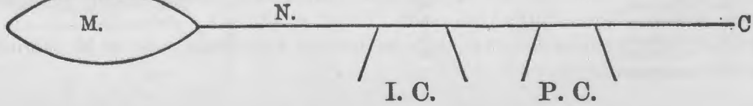
The use of a *myographion*—especially with a weight attached, as it seems Pflüger used it—had to be *dispensed with* in the first series of experiments, as my object was to obtain minimal contractions, which cannot be obtained with a myographion as these contractions are too feeble to raise or move the lever of this instrument.

The *distance between* the two irritating *electrodes* was 4–6^{mm}, which was also the distance between the polarizing poles. The distance between the two currents varied from 5-11^{mm}.

The *frogs* employed had been in captivity but a short time and were largely of the *temporaria* variety.

These experiments were especially guarded against the errors arising from the occurrence of "*secondary polarization*," and from *umpolar excitations*.

A descending polarizing current applied to a nerve above a descending irritating current.



Under these circumstances, if Pflüger's theory be true, the constant polarizing current must *always* cause the irritation to produce a stronger muscular contraction than when it is absent.

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
h. m.	1.			Rana temporaria.
	1st irritations...	Movements very slight	Movements more marked.	4 cells for polarization; 2 for irritation.
	2d irritations....	......do	......do	4 cells for polarization; 1 for irritation.
	3d irritations....	Movements less than before.	......do	Do.
	4th irritations...	Very slight movements	......do	Do.
	5th irritations...	......do	......do	Do.
	6th irritations...	......do	......do	Do.

In this, as in following experiments, the effect of the opening of the irritating was not noted, while that of closing alone was observed. During the polarization not only were the movements more marked, but they extended over a greater portion of the limb. It may be here remarked, what was forgotten when speaking of the "methods" of experimentation, that in these experiments the sciatic nerve of frogs was used.

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
h. m.	2.	2 cells, rheochord:		Rana temporaria.
	1st irritations...	2781 cent......2.	0.	Polarization with 2 Daniel cells.
	2d irritations....	1214 cent......1.	0. 5	
	3d irritations....	1318 cent......1.	1.	
	4th irritations...	1.	1.	
	5th irritations...	1009 cent......1. 5	1.	
	6th irritations...	2.	0. 5	
	3.			Rana temporaria.
	1st irritations...	2.	2.	Irritation (2 cells), 3109 cent.; polarization, 2 cells.
	2d irritations...	1.	3.	Irritation (2 cells), 3053 cent.; polarization, 2 cells.
	3d irritations....	1.	1.	Irritation (2 cells), 3045 cent.; polarization, 2 cells.
	4th irritations...	1.	1.	Do.
	5th irritations...	1. 5	3.	Irritation (2 cells), 3003 cent.; polarization, 2 cells.
	6th irritations...	1.	3.	
	7th irritations...	1.	3.	Time of experiment, 22 minutes.
	4.			Rana temporaria.
	1st irritations...	0.	2. 5	Polarization, 4 Daniel cells; irritation, 2 cells.
	2d irritations....	0.	2. 5	
	3d irritations....	0.	3.	
	5.			Rana temporaria.
10 15	1st irritations...	1.	0.	Polarization, 4 Daniels; irritation, 2 Daniels.
24	2d irritations....	2.	0. 5	
42	3d irritations....	1. 5	2.	Polarization, 1 Daniel.
11 01	4th irritations....	1. 5	2.	
	6.			Rana temporaria.
12 04	1st irritations...	0. 5	0.	Polarization, 4 Daniels; irritation, 2.
10	2d irritations....	0. 5	0. 5	
15	3d irritations....	0. 5	0.	
19	4th irritations...	0. 5	0.	
22	5th irritations...	0. 5	0.	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
	7.			
h. m.				Rana temporaria.
3 06	1st irritations...	0.5	4.	Polarization with 1 Daniel.
08	2d irritations....	0.5	4.	
19	3d irritations....	0.5	4.	
4 09	4th irritations...	0.5	0.5	
	8.			
				Rana temporaria.
9 58	1st irritations...	0.5	4.	Polarization, 1 Daniel.
10 02	2d irritations....	0.5	0.5	Diminished irritating current.
03½	3d irritations ..	0.5	0.	
05	4th irritations...	0.5	0.	
07	5th irritations...	0.5	0.	
	9.			
				Rana temporaria.
10 35	1st irritations...	1.	0.	Polarization, 4 Daniels.
36	2d irritations....	1.	0.	
38	3d irritations....	1.	4.	Polarization, 2 Daniels.
43	4th irritations...	1.	0.5	Polarization, 3 Daniels.
44	5th irritations...	1.	0.5	
45	6th irritations...	1.	0.5	
48	7th irritations...	1.	0.5	
53	8th irritations...	1.	1.	
58	9th irritations ..	1.	0.5	
11 06	10th irritations..	1.	1.	
	10.			
				Rana temporaria.
11 10	1st irritations...	1.	1.	Polarization, 4 Daniels.
22	2d irritations....	1.	0.5	
	11.			
				Rana temporaria.
11 40	1st irritations...	1.	4.	Polarization, 4 Daniels.
47	2d irritations....	1.	0.5	Polarization, 3 Daniels.
49	3d irritations....	1.	0.5	
	12.			
				Rana esculenta.
2 09	1st irritations...	1.	3.5	Weak irritating currents.
10	2d irritations....	1.	3.5	Do.
13	3d irritations....	1.	3.5	Do.
17	4th irritations ..	3.	3.	Strong irritating currents.
23	5th irritations...	3.	2.	Do.
25	6th irritations...	3.	2.	Do.
	13.			
				Rana temporaria.
2 35	1st irritations...	1.	3.	Rheochord (irrit.), 2458 cent.
42	2d irritations....	1.	0.5	Rheochord (irrit.), 2350 cent.
45	3d irritations....	1.	0.	Do.
48	4th irritations...	1.	0.	Do.
52	5th irritations...	1.	0.	Rheochord (irrit.), 2127 cent.
	14.			
				Rana esculenta.
3 27	1st irritations...	0.2	5.	Rheochord (irrit.), 2907 cent.
29	2d irritations....	0.2	5.	Do.
32	3d irritations....	2.5	1.	Rheochord (irrit.), 1793 cent.
35	4th irritations...	1.	5.	Rheochord (irrit.), 2781 cent.
40	5th irritations...	1.	5.	Do.
	15.			
				Rana esculenta.
4 02	1st irritations...	0.2	0.5	Rheochord (irrit.), 3058 cent.
06	2d irritations....	0.2	0.2	Rheochord (irrit.), 2562 cent.
10	3d irritations....	0.5	0.2	Rheochord (irrit.), 2249 cent.
13	4th irritations...	0.5	0.2	
16	5th irritations...	0.5	0.5	
20	6th irritations...	0.5	0.5	
30	7th irritations...	0.5	0.5	
35	8th irritations...	0.5	0.5	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
	16.			
h. m.		Rheochord:		Rana temporaria.
11 15	1st irritations	2781 cent......0.	0.	
20	2d irritations	2675 cent......0. 5	3. 5	
23	3d irritations	2675 cent......1. 5	2.	
25	4th irritations	2458 cent......1. 5	1.	
30	5th irritations	223 cent......3.	0. 5	
32	6th irritations	223 cent......3.	0. 5	
39	7th irritations	223 cent......3.	0. 5	
43	8th irritations	1634 cent......1. 5	1.	
45	9th irritations	2127 cent......0. 5	2.	
47	10th irritations	2127 cent......0. 5	2.	
47½	11th irritations	1413 cent......0. 5	2.	
48	12th irritations	1109 cent......0. 5	2.	
49	13th irritations	223 cent......1.	4.	
53	14th irritations	223 cent......0.	4.	
54	15th irritations	223 cent......0. 5	4.	
56	16th irritations	223 cent......0. 5	4.	
	17.			
		Rheochord:		Rana esculenta.
10 46	1st irritations	1893 cent......1. 5	0.	
54½	2d irritations	2016 cent......1. 5	5.	
57	3d irritations	223 cent......2.	4.	
58	4th irritations	1893 cent......0.	4.	
59	5th irritations	1713 cent......0.	4.	
59½	6th irritations	1634 cent......0.	3.	
11 00½	7th irritations	1526 cent......0.	3.	
01	8th irritations	1413 cent......0.	3.	
02	9th irritations	1308 cent......0.	3.	
02½	10th irritations	691 cent......0.	3.	
06	11th irritations	488 cent......0.	3.	
09	12th irritations	223 cent......0.	3.	
10	13th irritations	223 cent......0.	3.	
15	14th irritations	223 cent......0.	3.	
	18.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana temporaria.
9 45	1st irritations	2955 cent......1.	0.	
49	2d irritations	2955 cent......1.	0.	
50	3d irritations	2955 cent......0. 5	0.	
60	4th irritations	2955 cent......0.	0.	
10 02	5th irritations	2955 cent......0.	0.	
05	6th irritations	2401 cent......4.	4.	
07	7th irritations	2728 cent......4.	1.	
09	8th irritations	2728 cent......4.	1.	
12	9th irritations	2728 cent......0.	0.	
16	10th irritations	223 cent......4.	4.	
20	11th irritations	2728 cent......2.	0. 5	
22	12th irritations	2728 cent......2.	0. 5	
28	13th irritations	2728 cent......2.	0. 5	
34	14th irritations	2728 cent......2.	0. 5	
40	15th irritations	2728 cent......1. 5	0.	
43	16th irritations	2728 cent......1. 5	0. 5	
	19.			
		1 cell, rheochord:		Rana temporaria.
1 32	1st irritations	223 cent......5.	4.	
39	2d irritations	223 cent......0.	4.	
50	3d irritations	223 cent......0.	4.	
	20.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana temporaria.
2 10	1st irritations	3109 cent......0.	0.	
15	2d irritations	3179 cent......0.	4.	
19	3d irritations	3198 cent......0.	4.	
21	4th irritations	223 cent......3.	3.	
22	5th irritations	3198 cent......0.	0.	
36	6th irritations	3198 cent......0.	0.	
45	7th irritations	3198 cent......0.	0.	
47	8th irritations	2849 cent......2.	0.	
49	9th irritations	2295 cent......2.	2.	
50	10th irritations	223 cent......2.	2.	
3 05	11th irritations	3058 cent......0.	0.	
06	12th irritations	3194 cent......0.	0.	
14	13th irritations	3194 cent......0.	0.	
15	14th irritations	223 cent......1. 5	3.	
35	15th irritations	223 cent......1.	1.	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
	21.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana esculenta.
h. m.				
3 20	1st irritations ...	3109 cent......0.	0.	
23	2d irritations....	1847 cent......3.	0.	
24	3d irritations....	1413 cent......4.	1.	
27	4th irritations ..	223 cent .....5.	5.	
	22.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana temporaria.
9 00	1st irritations ..	3197 cent......0.	3.	
12	2d irritations....	3197 cent......0.	4.	
23	3d irritations....	3197 cent......0.	3.	
29	4th irritations ..	3197 cent......0.	2.	
30	5th irritations ..	223 cent......0.	3.	
31	6th irritations ..	3109 cent......0.	3.	
37	7th irritations...	1 cell ....5.	5.	
45	8th irritations...	1 cell .... 0.	3.	
56	9th irritations...	1 cell ....3.	5.	
10 08	10th irritations..	1 cell ....2.	2.	
18	11th irritations..	1 cell ....4.	3.	
25	12th irritations..	1 cell ....4.	2.	
30	13th irritations..	1580 cent .... 4.	0.	
35	14th irritations..	2728 cent .... 0.	0.	
40	15th irritations..	2728 cent .... 1.	2.	
45	16th irritations..	2728 cent......1.	2.	
50	17th irritations..	2728 cent......1.	2.	
55	18th irritations..	2728 cent......1.	4.	
11 00	19th irritations..	2728 cent .... 1.	3.	
21	20th irritations..	2728 cent .... 3.	1.	
26	21st irritations ..	2728 cent......4.	2.	
31	22d irritations ..	2728 cent......4.	0.	
36	23d irritations ..	2728 cent......3.	0. 5	
41	24th irritations..	2728 cent .... 3.	0. 5	
53	25th irritations..	2849 cent......5.	0.	
58	26th irritations..	2849 cent......1.	0.	
12. 00	27th irritations..	2849 cent......1.	0.	
06	28th irritations..	2849 cent......3.	0.	
	23.			
		Irritation, 1 cell, rheochord:	Polarization, 3 cells:	Rana temporaria.
2 00	1st irritations ..	3197 cent......0.	0.	
05	2d irritations....	3197 cent .....0.	0.	
3 03	3d irritations....	223 cent .... 5.	4.	
09	4th irritations ..	1793 cent .... 4.	2.	
14	5th irritations...	1793 cent......4.	0.	
16	6th irritations...	2510 cent......3.	0.	
21	7th irritations ..	2510 cent......4.	0.	
26	8th irritations...	2510 cent......2.	0.	
42	9th irritations...	2510 cent......2. 5	1. 5	
	24.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana temporaria.
8 54	1st irritations ...	3109 cent..... 0.	0.	
9 06	2d irritations....	2183 cent......3.	0.	
10	3d irritations....	2183 cent......0.	0.	
14	4th irritations...	2016 cent......2.	1.	
25	5th irritations...	1360 cent......3.	3.	
30	6th irritations ..	1360 cent......1.	1.	
36	7th irritations ..	1360 cent......0. 5	0. 5	
40	8th irritations ..	1360 cent 0. 5	0. 5	
	25.			
		Irritation, 1 cell, rheochord:	Polarization, 3 cells:	Rana temporaria.
10 14	1st irritations ..	3197 cent .... 0.	5.	
17	2d irritations....	3197 cent......0.	5.	
21	3d irritations ..	3197 cent .....0.	5.	
25	4th irritations ..	3058 cent .....0.	5.	
26	5th irritations ..	3003 cent......5.	5.	
29	6th irritations ..	3003 cent......5.	5.	
36	7th irritations ..	3003 cent......4.	5.	
41	8th irritations...	3003 cent .... 3.	5.	
46	9th irritations...	3058 cent......0.	5.	
50	10th irritations..	3058 cent......0.	5.	
52	11th irritations..	2955 cent......2.	5.	
54	12th irritations..	2955 cent .. ..2.	5.	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
h. m.				
57	13th irritations..	2955 cent......2.	5.	
11 04	14th irritations..	2955 cent......1.	5.	
07	15th irritations..	2955 cent......0.	5.	
11	16th irritations..	2955 cent......0.	4.	
21	17th irritations..	2955 cent......0.	5.	
	26.	Irritation, 1 cell, rheochord:	Polarization, 3 cells:	Rana esculenta.
9 27	1st irritations...	3197 cent......0.	5.	
32	2d irritations....	3197 cent ......0.	5.	
37	3d irritations....	3197 cent......0.	5.	
41	4th irritations...	3058 cent..... 1.	5.	
50	5th irritations...	3058 cent..... 2.	4.	
55	6th irritations ..	3058 cent......0.	4.	
10 03	7th irritations ..	3058 cent......0. 5	3.	
08	8th irritations ..	3058 cent......0. 5	4.	
13	9th irritations...	3058 cent......1.	4.	
16	10th irritations..	3058 cent......0.	4.	
20	11th irritations..	2955 cent......2.	0. 5	
22	12th irritations..	2849 cent......2.	1.	
24	13th irritations..	2728 cent......4.	2.	
27	14th irritations..	2728 cent......3.	0.	
29	15th irritations..	2350 cent......4.	2.	
32	16th irritations..	2350 cent ......4.	1.	
33	17th irritations..	223 cent......5.	5.	
35	18th irritations..	2350 cent......4.	1.	
11 32	19th irritations..	2562 cent......4.	5.	
33	20th irritations..	2562 cent......4.	5.	
34	21st irritations..	2849 cent..... 2.	5.	
35	22d irritations...	2955 cent......0. 5	5.	
37	23d irritations ..	2955 cent.. .. 0.	5.	
38	24th irritations..	2901 cent..... 2.	5.	
39	25th irritations..	2901 cent......3.	5.	
42	26th irritations..	3003 cent......2.	1.	
44	27th irritations..	3003 cent......3.	1.	
50	28th irritations..	3003 cent......0. 5	5.	But 1 polarizing cell.
51	29th irritations..	3003 cent......4.	0.	4 polarizing cells.
52	30th irritations..	3003 cent......5.	0. 5	Do.
53	31st irritations..	3003 cent......5.	2.	Do.
56	32d irritations ..	3003 cent..... 5.	2.	Do.
	27.	Irritation, 1 cell, rheochord:	Polarization, 3 cells:	Rana esculenta. Other leg of last frog.
11 12	1st irritations...	2781 cent......0.	5.	
15	2d irritations....	2675 cent......0. 5	5.	
30	3d irritations ...	2675 cent......0.	5.	
31	4th irritations...	2562 cent..... 2.	5.	
32	5th irritations...	2562 cent..... 1.	5.	
40	6th irritations...	3058 cent......0.	5.	
41	7th irritations ..	3003 cent......1.	5.	
46	8th irritations ..	3003 cent ......2.	4.	
48	9th irritations...	3003 cent......2.	4.	
53	10th irritations..	3003 cent......0.	5.	
54	11th irritations..	3003 cent......0.	4.	
55	12th irritations..	3003 cent......0.	4.	
	28.	Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana temporaria.
1 56	1st irritations...	3109 cent......1.	4.	
58	2d irritations....	3109 cent 0. 5	4.	Polarization, 1 cell.
59	3d irritations....	3179 cent......0.	4.	Do.
2 00	4th irritations...	3179 cent......0.	4.	Polarization, 4 cells.
05	5th irritations...	3179 cent..... 0.	4.	Do.
06	6th irritations ..	3179 cent......0.	2.	Polarization, 1 cell.
10	7th irritations ..	3003 cent ..... 1.	3.	Do.
12	8th irritations...	3003 cent.. .. 2.	4.	Polarization, 4 cells.
27	9th irritations ..	3003 cent......0. 5	5.	Do.
29	10th irritations..	3003 cent......0. 5	5.	Polarization, 1 cell.
33	11th irritations..	3003 cent......0. 5	5.	Do.
34	12th irritations..	3003 cent......0.	4.	Polarization, 4 cells.
40	13th irritations..	3003 cent......3.	4.	Do.
43	14th irritations..	3003 cent ......2.	4.	Polarization, 1 cell.
45	15th irritations..	1160 cent ......4.	5.	Do.
46	16th irritations..	1160 cent......4.	5.	Polarization, 4 cells.
46½	17th irritations..	341 cent..... 4.	4.	Do.
47½	18th irritations..	341 cent..... 4.	4.	Polarization, 1 cell.

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
h. m.				
2 48	19th irritations..	3003 cent......1.	0.	Polarization, 1 cell.
49	20th irritations..	3003 cent......1. 5	3.	Polarization, 4 cells.
52	21st irritations..	3003 cent..... 0. 5	4.	Do.
53	22d irritations...	3003 cent......0. 5	0.	Polarization, 1 cell.
54	23d irritations...	3003 cent......4.	4.	Do.
55	24th irritations..	3003 cent......4.	4.	Polarization, 4 cells.
58	25th irritations..	2955 cent......0. 5	0.	Polarization, 1 cell.
3 00	26th irritations..	601 cent......4. 5	5.	Polarization, 4 cells.
01	27th irritations..	691 cent......4. 5	5.	Polarization, 1 cell.
02	28th irritations..	2781 cent......1.	3.	Do.
16	29th irritations..	2675 cent......3.	0.	Polarization, 4 cells.
18	30th irritations..	2675 cent......2.	1.	Polarization, 1 cell.
	29.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells, rheochord:	Rana temporaria.
11 29	1st irritations...	3197 cent......2.	55 cent........5.	Polarization current from 1 cell.
31	2d irritations....	3197 cent......2.	55 cent........5.	Do.
33	3d irritations ...	3176 cent......0.	57 cent........3.	Do.
45	4th irritations...	3176 cent......0.	53 cent........2.	Do.
50	5th irritations...	3176 cent......0.	56 cent........1.	Do.
55	6th irritations...	3176 cent......0. 5	56 cent........1.	Do.
	30.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells, rheochord:	Rana temporaria.
9 29	1st irritations...	3013 cent......0.	57 cent....... 1. 5	
35	2d irritations ...	2925 cent......0.	57 cent........3.	
36	3d irritations....	2925 cent......0.	38 cent ...... 4.	
37	4th irritations...	2925 cent......2.	38 cent........5.	
58	5th irritations...	2875 cent......0.	48 cent........2.	
10 01	6th irritations...	2849 cent......0.	38 cent........1.	
	31.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells, rheochord:	Rana temporaria.
9 00	1st irritations...	223 cent...... 0. 5	10 cent........1.	
05	2d irritations....	223 cent......0.	10 cent........1.	
10	3d irritations....	223 cent...... 0. 5	10 cent........1.	
	32.			
		Irritation, 1 cell, rheochord:	Polarization, 1 cell, rheochord:	Rana temporaria.
9 20	1st irritations ...	3109 cent......1.	48 cent........1.	
9 30	2d irritations ...	3025 cent .... 2.	30 cent ....3.	
31	3d irritations ...	3025 cent......1.	30 cent........2.	
38	4th irritations...	3025 cent......0. 5	30 cent....... 2.	
43	5th irritations ..	3025 cent .... 2.	30 cent........5.	
45	6th irritations ..	2955 cent......2.	30 cent........2.	
48	7th irritations...	2955 cent......3.	30 cent ....2.	
49	8th irritations...	2555 cent......3.	30 cent........3.	
52	9th irritations ..	2955 cent......2.	30 cent .. ..5.	
55	10th irritations..	2955 cent ......2.	30 cent........2.	
10 00	11th irritations..	2781 cent......4.	30 cent ....5.	
02	12th irritations..	2781 cent......5.	30 cent ....5.	
06	13th irritations..	2875 cent......3.	30 cent ....4.	
07	14th irritations..	2875 cent......3.	30 cent........3.	
08	15th irritations..	2875 cent......1.	30 cent........3.	
10	16th irritations..	2875 cent......0.	30 cent........0.	
12	17th irritations..	2728 cent......2.	30 cent ...... 5.	
13	18th irritations..	2728 cent......4.	30 cent........4.	
14	19th irritations..	2728 cent......3. 5	30 cent........4.	
16	20th irritations..	2728 cent......4.	30 cent........4. 5	
18	21st irritations ..	2728 cent......3. 5	49 cent....... 3. 5	
19	22d irritations...	2728 cent......3.	49 cent....... 3.	
22	23d irritations...	2728 cent......0. 5	49 cent........2.	
35	24th irritations..	2675 cent ..... 5.	49 cent ....5.	
37	25th irritations..	2700 cent..... 3.	49 cent........3.	
40	26th irritations..	2700 cent......3.	49 cent........3.	
44	27th irritations..	2700 cent......3.	49 cent....... 4.	
47	28th irritations..	2700 cent......3.	49 cent........4.	
50	29th irritations..	2700 cent......4.	49 cent........4.	
52	30th irritations..	2700 cent......2.	49 cent........3.	
57	31st irritations..	2700 cent ......2.	49 cent........3.	
58	32d irritations...	2700 cent......2. 5	49 cent........3.	
11 01	33d irritations...	2700 cent .... 2.	49 cent........2. 5	
04	34th irritation...	2700 cent......3.	49 cent ....4.	
14	35th irritations..	2700 cent......4.	49 cent 4. 5	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
	33.	Irritation, 1 cell, rheochord:	Polarization, 1 cell, rheochord:	Rana temporaria.
h. m.				
1 20	1st irritations...	2781 cent......3. 5	49 cent........4.	
21	2d irritations....	2901 cent......3.	49 cent........4.	
22½	3d irritations....	2901 cent......2. 5	10 cent........4.	
24	4th irritations...	2901 cent......2.	10 cent........4.	
40	5th irritations...	2901 cent......2.	10 cent........3.	
47	6th irritations...	2675 cent......2.	10 cent....... 3.	
2 01	7th irritations...	2675 cent......2.	10 cent........3.	
04	8th irritations..	2675 cent .... 2.	10 cent ...... 3.	
08	9th irritations...	2675 cent......2.	10 cent........2.	
10	10th irritations..	2675 cent......2.	10 cent........3.	
11	11th irritations..	2675 cent......2. 5	30 cent........3.	
16	12th irritations..	2675 cent......2.	30 cent........3.	
18	13th irritations..	2675 cent .... 1.	30 cent ......3.	
24	14th irritations..	2675 cent......1.	30 cent.... .. 2.	
27	15th irritations..	2562 cent .... 1.	30 cent.... .. 2.	
28	16th irritations..	2562 cent......2.	30 cent........2.	
30	17th irritations..	2562 cent .... 2.	30 cent........2.	
31	18th irritations..	2562 cent......2.	30 cent ..... 2.	
34	19th irritations..	2562 cent......2.	30 cent.... .. 2.	
38	20th irritations..	2016 cent......2.	30 cent 2. 5	
41	21st irritations ..	2016 cent......2.	30 cent.... .. 2. 5	
42	22d irritations...	2016 cent......2.	30 cent........2.	
44	23d irritations...	2127 cent .... 2.	30 cent 2. 5	
45	24th irritations..	2127 cent......2.	30 cent........2.	
50	25th irritations .	2127 cent......1. 5	30 cent ...... 2.	
52	26th irritations..	2127 cent......1.	30 cent.. ......2.	
	34.	Irritation, 1 cell, rheochord:	Polarization, 1 cell, rheochord:	Rana temporaria.
9 39	1st irritations...	3169 cent......1.	10 cent........2.	
40	2d irritations....	3169 cent......0. 5	30 cent........1. 5	
44	3d irritations....	3169 cent......0. 5	30 cent........0. 5	
46	4th irritations...	3189 cent......0. 5	30 cent........1.	
	35.	Irritation, 1 cell, rheochord:	Polarization, 1 cell:	Other leg of last frog.
10 06	1st irritations ..	2781 cent 1. 5	10 cent........2.	
10	2d irritations ...	2781 cent......0. 5	10 cent........1. 5	
12	3d irritations ...	2781 cent......0. 5	10 cent........0. 5	
14	4th irritations...	2781 cent .....1.	10 cent ...... 1.	
17	5th irritations...	2781 cent......0. 5	30 cent..... 1.	
20	6th irritations...	2781 cent......0. 5	30 cent........0. 5	
35	7th irritations...	1526 cent......0. 5	30 cent........1.	

In the preceding experiments the muscular contractions caused by the *closing* of the circuit were used to measure the excitability of the nerves, and are represented by the figures in columns 3 and 4. Of these figures 5 represents maximal and 0.5 minimal contractions.

Out of the thirty-five experiments just given, but nine (experiments 1, 4, 7, 14, 17, 27, 29, 30, and 31) go to confirm the theory of Pflüger, while fourteen (experiments 2, 6, 8, 9, 10, 11, 13, 15, 16, 18, 21, 22, 23, and 24) give results in direct opposition with it. Of the remaining twelve experiments, in two (5 and 12) an increased excitability of the nerve was produced by the polarizing current in one-half the irritations. In ten experiments (3, 19, 20, 25, 26, 28, 32, 33, 34, and 35) Pflüger's result was usually obtained.

From this we must conclude that Pflüger's theory does not hold good as regards the effect of a descending polarizing current on the excitability of the nerves, as measured by means of the muscular contractions produced by the closing of an electric circuit.

In the following experiments the muscular contractions noted were produced by the *opening* of the circuit.

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
	36.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells:	Rana temporaria.
h. m.	1st irritations...	2900 cent......2.	0.	
	2d irritations....	2695 cent .... 2.	0.	
	3d irritations ...	2770 cent .....2.	0. 5	
	4th irritations...	1526 cent .... 2.	0. 5	
	5th irritations ..	1308 cent......0. 5	0. 5	
	6th irritations ..	1000 cent......0. 5	0. 5	
	37.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana temporaria.
	1st irritations...	3.	3.	
	2d irritations....	3.	3.	
	3d irritations ...	3109 cent......0 5	3.	
	4th irritations...	3109 cent 0. 5	3.	
	5th irritations...	3109 cent......0. 5	0.	
	38.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana temporaria.
2 46	1st irritations...	3109 cent 0. 5	0. 5	
3 05	2d irritations...	3109 cent......0. 5	2.	
13	3d irritations....	3109 cent .... 2.	2.	
17	4th irritations...	3109 cent 0. 5	2.	
25	5th irritations...	3003 cent..... 0. 5	2.	
30	6th irritations...	3003 cent......0. 5	2.	
35	7th irritations...	3003 cent......0. 5	2.	
	39.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana esculenta.
11 20	1st irritations...	2675 cent......0.	2.	
25	2d irritations....	2675 cent......0.	0.	
32	3d irritations....	223 cent......1.	0. 5	
39	4th irritations...	223 cent......1.	0.	
43	5th irritations...	1634 cent......1.	0.	
	40.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana temporaria.
1 05	1st irritations...	2458 cent......1.	0.	
12	2d irritations....	2350 cent......1. 5	0.	
15	3d irritations....	2350 cent......1. 5	0.	
20	4th irritations...	2350 cent......1. 5	0.	
	41.			
		Irritation, 1 cell:	Polarization, 4 cells:	
1 45	1st irritations...	3109 cent......0. 5	1.	
46	2d irritations....	3109 cent......0. 5	4.	
47	3d irritations ...	3109 cent......0.	3.	
49	4th irritations...	3109 cent......0.	5.	
	42.			
		Irritation, 1 cell:	Polarization, 3 cells:	Rana temporaria.
12 00	1st irritations...	0.	3.	
04	2d irritations....	0.	3.	
08	3d irritations....	0.	3.	
	43.			
		Irritation, 1 cell, rheochord:	Polarization, 3 cells:	Rana esculenta.
2 00	1st irritations...	2562 cent......1.	3.	
04	2d irritations....	2249 cent......1. 5	0. 5	
08	3d irritations....	2249 cent......1. 5	0. 5	
11	4th irritations...	2249 cent......1. 5	0.	
14	5th irritations...	2249 cent......1. 5	0.	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
	44.			
		Irritation, 1 cell, rheochord:	Polarization, 3 cells:	Rana esculenta.
h. m.				
4 07	1st irritation ...	3189 cent.......0. 5	3.	
09	2d irritations....	3189 cent.......0. 5	2. 5	
13	3d irritations....	3189 cent.......0. 5	2. 5	
	45.			
		Irritation, 1 cell:	Polarization, 4 cells:	Rana temporaria.
5 00	1st irritations ...	0. 5	3.	
07	2d irritations ...	0. 5	0.	
09	3d irritations ...	0. 5	0.	
	46.			
		Irritation, 1 cell:	Polarization, 4 cells:	
11 03	1st irritations ...	1.	0.	
05	2d irritations ...	1.	0.	
08	3d irritations....	1.	5.	Polarization, 2 cells.
14	4th irritations...	1.	0. 5	Polarization, 4 cells.
15	5th irritations...	1.	0. 5	
16	6th irritations...	1.	0.	
18	7th irritations ..	2.	0. 5	
23	8th irritations...	1.	0. 5	
28	9th irritations...	1.	0. 5	
12 06	10th irritations..	0. 5	0. 5	
	47.			
		Irritation, 1 cell:	Polarization, 4 cells:	Rana esculenta.
9 05	1st irritations ...	1.	0.	
12	2d irritations....	1.	0.	
14	3d irritations....	0. 5	0.	
15	4th irritations...	0. 5	0.	
17	5th irritations...	0. 5	0.	
	48.			
		Irritation, 1 cell:	Polarization, 2 cells:	Rana temporaria.
2 56	1st irritations ...	1.	3.	
59	2d irritations....	1.	3.	
3 01	3d irritations....	1.	3.	
43	4th irritations...	0. 5	0. 5	
	49.			
		Irritation, 1 cell:	Polarization, 4 cells:	Rana temporaria.
2 09	1st irritations ...	1.	0.	
12	2d irritations ...	1.	0.	
22	3d irritations....	2.	0. 5	
	50.			
		Irritation, 1 cell:	Polarization, 4 cells:	Rana temporaria.
8 00	1st irritations ..	1.	0. 5	
06	2d irritations....	1.	0.	
11	3d irritations....	1.	0. 5	
	51.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana esculenta.
8 29	1st irritations ...	223 cent........1. 5	0.	
32	2d irritations ..	223 cent........0.	0.	
34	3d irritations....	223 cent 1. 5	0.	
38	4th irritations...	223 cent........1. 5	0.	
	52.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana temporaria.
9 45	1st irritations ...	2955 cent......1.	0. 5	
47	2d irritations....	2955 cent......1.	3.	Polarization, 1 cell.
50	3d irritations....	2955 cent......1.	0. 5	
10 00	4th irritations...	2955 cent......0. 5	0. 5	
05	5th irritations...	2401 cent......3.	3.	
09	6th irritations...	2728 cent......3.	0. 5	
12	7th irritations...	2728 cent......2. 5	3.	
16	8th irritations...	223 cent......4.	4.	
20	9th irritations...	2728 cent..... 2.	0. 5	
22	10th irritations..	2728 cent......2.	3.	
28	11th irritations..	2728 cent......2.	0. 5	
40	12th irritations..	2728 cent..... 1. 5	0.	
43	13th irritations..	2728 cent......1. 5	0.	
54	14th irritations..	2728 cent......1. 5	0. 5	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
	53.			
		Irritation, 1 cell, rheochord:	Polarization:	Rana temporaria.
h. m.				
2 10	1st irritations...	3109 cent......1. 5	4 cells..........0.	
15	2d irritations....	3179 cent ..... 0.	1 cell ....3.	
19	3d irritations ...	223 cent......3.	4 cells. ....1.	
21	4th irritations...	3198 cent......0.	1 cell..........3.	
22	5th irritations ..	3198 cent......0.	1 cell..........3.	
36	6th irritations ..	3198 cent......0.	1 cell..........3.	
45	7th irritations...	2849 cent......0.	1 cell..........3.	
47	8th irritations...	2295 cent......0	1 cell..........3.	
49	9th irritations...	223 cent ......3.	1 cell..........3.	
50	10th irritations..	3058 cent ......0.	1 cell......... 3.	
3 05	11th irritations..	3194 cent......0.	1 cell..........3.	
06	12th irritations..	3194 cent......0.	1 cell..........3.	
14	13th irritations..	223 cent 1. 5	3.	
15	14th irritations..	223 cent......1. 5	3.	
	54.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana temporaria.
2 30	1st irritations...	3197 cent ......3.	0.	
42	2d irritations....	3197 cent......2.	0.	
52	3d irritations....	3197 cent......2.	0.	
	55.			
		Irritation, 1 cell:	Polarization, 2 cells:	Rana temporaria.
9 05	1st irritations...	3197 cent......0.	4.	
10	2d irritations....	3197 cent......0.	5.	
18	3d irritations ...	3197 cent...... 0.	4.	
28	4th irritations...	3187 cent......0.	3.	
40	5th irritations...	3187 cent ..... 0.	2.	
45	6th irritations...	3187 cent......0.	0. 5	
10 07	7th irritations...	1793 cent......0.	3.	
09	8th irritations...	223 cent......0.	0.	
	56.			
		Irritation, 1 cell, rheochord:	Polarization, 3 cells:	Rana temporaria.
10 29	1st irritations...	3003 cent......5.	5.	
36	2d irritations....	3003 cent ..... 4.	5.	
41	3d irritations ...	3003 cent ......3.	5.	
46	4th irritations...	3058 cent......0.	5.	
50	5th irritations...	3058 cent......0.	5.	
52	6th irritations ..	2955 cent ......2.	5.	
54½	7th irritations...	2955 cent......2.	5.	
57½	8th irritations...	2955 cent......0.	5.	
11 05	9th irritations ..	2955 cent......1.	5.	
07	10th irritations..	2955 cent......0. 5	5.	
11½	11th irritations..	2955 cent......0.	5.	
17	12th irritations..	2955 cent......0.	5.	
21	13th irritations..	2955 cent......0.	5.	
	57.			
		Irritation, 1 cell, rheochord:	Polarization:	Rana temporaria.
11 15	1st irritations...	2675 cent......0.	4 cells ....0.	
31	2d irritations ...	2562 cent......0.	4 cells..........0.	
46	3d irritations....	2955 cent ......0.	4 cells..........1.	
48	4th irritations ..	2955 cent ......0.	4 cells ....1.	
53	5th irritations...	2955 cent......0.	4 cells ....1.	
54	6th irritations...	2955 cent......0.	1 cell...... .. 0. 5	
55	7th irritations...	2955 cent......0.	1 cell..........0.	
	58.			
		Irritation, 1 cell:	Polarization:	Rana temporaria.
2 00	1st irritations...	3179 cent......0.	4 cells..........0.	
05	2d irritations....	3179 cent......0.	4 cells..........0.	
06	3d irritations....	3179 cent......0.	1 cell ....2.	
10	4th irritations ..	3003 cent......0.	1 cell..........4.	
12	5th irritations...	3003 cent......0.	4 cells..........0.	
40	6th irritations ..	3003 cent ......0.	4 cells..........0.	
43	7th irritations...	3003 cent......0.	1 cell..........4.	
45	8th irritations...	1160 cent ..... 0.	1 cell..........0.	
46	9th irritations ..	1160 cent......0.	4 cells..........1.	
46½	10th irritations..	341 cent......0.	4 cells..........1.	
47½	11th irritations..	341 cent ......0.	1 cell..........1.	
48	12th irritations..	3003 cent......0.	1 cell ....3.	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
h. m.				
2 49	13th irritations..	3003 cent.......0.	4 cells..........0.	
52	14th irritations..	3003 cent.......0.	4 cells......... 0.	
53	15th irritations..	3003 cent.......0.	1 cell...........3.	
54	16th irritations..	3003 cent...... 0.	1 cell ....1.	
55	17th irritations..	3003 cent.......0.	4 cells..........0.	
58	18th irritations..	2955 cent.......0.	1 cell...........2.	
3 00	19th irritations..	691 cent.......0.	4 cells..........0.	
01	20th irritations..	691 cent.......0.	1 cell...........1.	
02	21st irritations..	2781 cent.......0.	1 cell...........0.	
16	22d irritations...	2675 cent.......1.	4 cells..........0.	
18	23d irritations...	2675 cent.......1.	1 cell...........0.	
	59.	Irritation, 1 cell, rheochord:	Polarization, 4 cells, rheochord:	Rana temporaria.
2 19	1st irritations...	3197 cent.......0. 5.	3 cent......... 5.	
21	2d irritations ..	3197 cent 0. 5	3 cent....... 5.	
24	3d irritations....	3179 cent.......0.	0 cent..........3.	
34	4th irritations...	3179 cent.......0.	5 cent..........3.	
40	5th irritations...	3179 cent .... 0.	2 cent..........3.	

In the last twenty-four experiments it will be seen that an augmented excitation of the nerve for the breaking of an irritating current to the side of the kathode of a constant current was produced, as a rule, in but ten experiments (38, 42, 48, 53, 55, 56, 57, 58, and 59). A diminished excitability of the nerve occurred under these circumstances in fourteen experiments (36, 37, 39, 40, 41, 43, 45, 46, 47, 49, 50, 51, 52, and 54).

The results obtained in these fifty-nine experiments cannot be explained by the theory which demands an increased excitability of the nerve to the side of the kathode of the constant or polarizing current.

In searching for an explanation of these varying results, it occurred to me that the nerves and muscles on which these experiments (as also those of Pflüger) were made could hardly be considered as being in a normal state, in spite of the precautions used. The differences in the results could then be explained by referring them to the changes taking place in a dying nerve or muscle, which changes have been so little studied. To determine whether or not this was the explanation, a series of experiments were made on the uninjured nerve in its normal position. Copper electrodes were covered with wax, except at the point where they touch the nerve and passed underneath this structure, which was then experimented upon. The *making* of the circuit was observed in the following experiments:

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
	60.	Irritation, 1 cell, rheochord:	Polarization, 1 cell, rheochord:	Rana temporaria. Whenever the nerve showed signs of becoming dry in any of the following experiments it was moistened with a .015 solution of pure chloride of sodium.
h. m.				
3 06	1st irritations...	3003 cent...... 0.	10 cent ...... 0.	
10	2d irritations....	3003 cent ......0.	55 cent....... 0.	
15	3d irritations ...	2781 cent.......0.	55 cent....... 4.	
16	4th irritations ..	2781 cent.......0.	10 cent.........1.	
16½	5th irritations...	2781 cent.......0.	55 cent.........3.	
20	6th irritations...	2781 cent.......0.	55 cent ....0.	
32	7th irritations...	1739 cent.......2.	55 cent ....2.	
34	8th irritations...	1739 cent.......2.	55 cent.........2.	
36	9th irritations...	1739 cent.......2.	10 cent.........2.	
4 00	10th irritations..	1739 cent.......2.	50 cent.........4.	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
	61.	Irritation, 1 cell, rheochord:	Polarization, 1 cell, rheochord:	**Rana temporaria.**
h. m.				
4 15	1st irritations...	1951 cent......0.	50 cent........0.	
20	2d irritations....	341 cent......3.	10 cent ....3.	
21	3d irritations....	1214 cent ......2.	50 cent ....5.	
22	4th irritations...	1214 cent 0. 5	10 cent ...... 5.	
23	5th irritations...	1214 cent......0. 5	10 cent........3.	
24	6th irritations...	1214 cent......0. 5	10 cent........0.	
25	7th irritations...	1214 cent......0. 5	50 cent........0.	
50	8th irritations...	2016 cent......3.	49 cent...... .0.	**Electrodes brought nearer to each other.**
	62.	Irritation, 1 cell, rheochord:	Polarization, 1 cell, rheochord:	**Rana temporaria.**
11 15	1st irritations ..	1526 cent......0.	49 cent....... 0.	
53	2d irritations ...	1009 cent .... 1.	49 cent ... .. 0.	
54	3d irritations....	888 cent......0.	49 cent........0.	
55	4th irritations...	888 cent......1.	49 cent ....0.	
56	5th irritations...	888 cent......1.	10 cent ...... 0.	
57	6th irritations...	888 cent......0.	49 cent........0.	
58	7th irritations...	888 cent......0. 5	10 cent........0.	
	63.	Irritation, 1 cell, rheochord:	Polarization, 1 cell, rheochord:	**Rana temporaria.**
12 10	1st irritations ..	888 cent 0. 5	10 cent ....3.	
10½	2d irritations ..	888 cent......0. 5	49 cent........0. 5	
11	3d irritations ...	888 cent......0.	49 cent .. ....2.	
11½	4th irritations ..	888 cent .... 0.	10 cent ...... 2.	
15	5th irritations...	888 cent..... 0. 5	10 cent........0.	
16	6th irritations...	888 cent......1.	49 cent ....0.	
17	7th irritations...	888 cent......0. 5	49 cent........0. 3	
18	8th irritations...	888 cent......0. 5	10 cent........0. 3	
	64.	Irritation, 1 cell, rheochord:	Polarization, 1 cell, rheochord:	**Rana esculenta.**
10 00	1st irritations ..	2618 cent......0. 5	10 cent 0. 5	**Distance between polarizing and irritating electrodes 2.5 mm.**
08	2d irritations....	2618 cent......0.	54 cent........4.	
10	3d irritations....	2618 cent ......2.	10 cent....... 3.	
12	4th irritations...	2562 cent......3.	10 cent........3.	
14	5th irritations...	2562 cent......2. 5	10 cent........3.	
16	6th irritations ..	2678 cent......0. 5	10 cent 0. 5	
25	7th irritations...	2678 cent......0. 5	55 cent ....1.	
27	8th irritations...	2678 cent......0. 5	55 cent........0. 5	
	65.	Irritation, 1 cell, rheochord:	Polarization, 1 cell, rheochord:	**Rana escnlenta.**
10 40	1st irritations...	2675 cent......0. 5	54 cent 0. 5	**Distance between electrodes 5 mm.**
50	2d irritations ...	2618 cent......0.	52 cent........0. 5	
52	3d irritations....	2618 cent......0.	52 cent........0. 5	
54	4th irritations ..	2618 cent......0.	10 cent........1.	
	66.	Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	**Rana esculenta.**
11 19	1st irritations...	1847 cent 0. 5	10 cent....... 1.	
20	2d irritations....	1847 cent......0. 5	50 cent........2.	
21	3d irritations ..	1847 cent......0. 5	50 cent........0.	
22	4th irritations...	1847 cent......0. 5	10 cent........0.	
23	5th irritations...	2016 cent......0.	55 cent........2.	
27	6th irritations...	2562 cent......0.	10 cent........0. 5	
2 28	7th irritations...	2618 cent......0.	10 cent........0. 5	
35	8th irritations ..	2728 cent......0.	10 cent........0. 5	
36	9th irritations ..	2618 cent......0.	10 cent........0. 5	
37	10th irritations..	2618 cent......0.	55 cent........0. 5	
	67.	Irritation, 1 cell, rheochord:	Polarization, 4 cells, rheochord:	**Rana temporaria.**
3 17	1st irritations ..	1413 cent......0.	50 cent........4.	**Distance between electrodes 3 rnm.**
20	2d irritations....	1634 cent ......0.	50 cent........2.	
22	3d irritations....	1634 cent......0.	50 cent........2.	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
	68.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells, rheochord:	Rana temporaria.
h. m.				
10 35	1st irritations...	1951 cent 1.5	57 cent........1.5	
42	2d irritations....	2295 cent......0.	57 cent ...... 2.	
43	3d irritations....	2295 cent......1.	57 cent........1.	
11 15	4th irritations...	1526 cent......0.5	57 cent........0.5	
16	5th irritations...	1526 cent......0.2	57 cent........1.	
17	6th irritations...	1526 cent......0.5	57 cent........0.5	
18	7th irritations...	1526 cent......0.5	10 cent........0.5	
19	8th irritations...	1526 cent......1.	10 cent........0.5	
20	9th irritations...	1523 cent......0.5	10 cent 0.5	
30	10th irritations..	1526 cent 0.5	10 cent........0.5	
37	11th irritations .	1526 cent 0.5	10 cent..... .. 0.5	
45	12th irritations..	1526 cent......0.5	57 cent........0.5	
46	13th irritations..	1526 cent 0.5	57 cent........0.5	
48	14th irritations..	1526 cent......0.5	10 cent....... 0.5	
	69.			
		Irritation, 1 cell, rheochord:	Polarization, 1 cell, rheochord:	Rana temporaria. Distance between electrodes 8 mm.
2 35	1st irritations...	2675 cent ......0.	10 cent........0.	
3 00	2d irritations....	2618 cent......0.5	58 cent........1.	
03	3d irritations ...	2618 cent......0.	58 cent........2.	

Out of the ten experiments made in this manner, in six (60, 64, 65, 66, 67, and 69) the polarizing current produced an increased excitability, and failed to produce this effect in four experiments.

In the following experiments, made after the same plan, the muscular contractions following the opening of the irritating current are recorded.

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
	70.			
		Irritation, 1 cell, rheochord:	Polarization, 1 cell, rheochord:	Rana temporaria.
h. m.				
2 15	1st irritations...	2728 cent......1.5	10 cent.. ......2.	
22	2d irritations....	2728 cent......2.	57 cent........2.	
24	3d irritations ...	2728 cent......0.	57 cent........0.5	
25	4th irritations ..	2728 cent......0.	10 cent........0.5	
35	5th irritations...	2675 cent 0.5	10 cent........0.5	
36	6th irritations...	2675 cent......0.5	10 cent........1.	
37	7th irritations ..	2675 cent 0.5	58 cent........0.5	
45	8th irritations...	2618 cent......0.5	58 cent........1.	
47	9th irritations ..	2618 cent......0.	58 cent........0.5	
3 00	10th irritations..	2618 cent......0.5	58 cent........1.	
03	11th irritations..	2618 cent......0.5	58 cent........1.	
08	12th irritations..	2618 cent......0.	58 cent.. ......2.	
	71.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells, rheochord:	Rana temporaria.
11 15	1st irritations...	1526 cent......2.5	57 cent........3.	
16	2d irritations....	1526 cent ......3.	57 cent........3.	
17	3d irritations....	1526 cent......0.5	57 cent........0.5	
18	4th irritations ..	1526 cent ......3.	10 cent........3.	
19	5th irritations ..	1526 cent ......3.	10 cent........3.	
20	6th irritations...	1526 cent......0.5	10 cent........2.	
30	7th irritations...	1526 cent......1.	10 cent........1.5	
45	8th irritations ..	1526 cent......0.5	57 cent........0.5	
46	9th irritations .	1526 cent......0.5	57 cent........0.5	
48	10th irritations..	1526 cent......0.5	57 cent........0.5	
	72.			
		Irritation, 1 cell, rheochord:	Polarization, 1 cell, rheochord:	Rana esculenta.
10 21	1st irritations...	2675 cent......1.5	15 cent........3.	
45	2d irritations ..	2618 cent......0.5	10 cent........1.5	
46	3d irritations....	2618 cent......0.5	50 cent........1.5	
49	4th irritations.	1847 cent......1.	10 cent........1.	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
h. m.				
10 50	5th irritations ..	1847 cent......1.	50 cent........2.	
53	6th irritations...	2016 cent......1.	55 cent........2.	
57	7th irritations...	2562 cent......0. 5	55 cent........1.	
58	8th irritations...	2618 cent......0. 5	55 cent........1.	
11 05	9th irritations...	2728 cent 0. 5	10 cent........1.	
06	10th irritations..	2618 cent......0. 5	10 cent........1.	
07	11th irritations..	2618 cent......0. 5	55 cent........1. 5	
	73.			
		Irritation, 1 cell, rheochord:	Polarization, 1 cell, rheochord:	Rana temporaria.
11 15	1st irritations...	1526 cent......0. 5	49 cent........1.	
12 00	2d irritations....	888 cent......2.	10 cent........3.	
00½	3d irritations....	888 cent......2.	49 cent........3.	
01	4th irritations...	888 cent......2.	49 cent........3.	
01½	5th irritations ..	888 cent......2.	10 cent........3.	
07	6th irritations...	888 cent 0. 5	49 cent........0. 2	
08	7th irritations...	888 cent......1.	10 cent........0. 2	
	74.			
		Irritation, 1 cell, rheochord:	Polarization, 1 cell, rheochord:	Rana temporaria.
4 15	1st irritations ..	1957 cent......0. 5	50 cent........1. 5	
17	2d irritations....	1957 cent......0. 5	10 cent........0. 5	
20	3d irritations....	341 cent......5.	10 cent........5.	
21	4th irritations ..	1214 cent......5.	50 cent........5.	
22	5th irritations...	1214 cent......5.	10 cent........5.	
23	6th irritations...	1214 cent......5.	10 cent........5.	
50	7th irritations ..	2016 cent......2.	49 cent........3.	
	75.			
		Irritation, 1 cell, rheochord:	Polarization, 1 cell, rheochord:	Rana temporaria.
3 06	1st irritations...	3003 cent 0. 2	10 cent........3.	
08	2d irritations....	3003 cent......0.	55 cent........3.	
10	3d irritations....	3003 cent......0. 5	55 cent........2.	
15	4th irritations...	2781 cent......2.	55 cent........3.	
16	5th irritations ..	2781 cent......0.	10 cent........3.	
16½	6th irritations...	2781 cent......0.	55 cent........3.	
20	7th irritations ..	2781 cent......1.	55 cent........2.	

In four of these experiments the polarizing current usually produced an increased excitability of the nerve to the side of the negative pole; while in two experiments the polarization seemed to have little or no influence on the effect of the irritating current.

A "half-saturated" solution of pure chloride of sodium was now substituted for the irritating current and the experiment repeated in this manner. The solution was applied to the nerve near the muscle and 5^{mm} below the point of application of the descending polarizing current.

EXPERIMENT 76.—Sciatic nerve and gastrocnemius muscle of a Rana esculenta.

Polarizing current from 1 *Daniel.*

First irritations.—Salt solution alone=1. With polarization, 3.
Second irritations.—Salt solution alone=1. With polarization, 0
Third irritations.—Salt solution alone=1. With polarization, 0.
Fourth irritations.—Salt solution alone=1. With polarization, 0.
Fifth irritations.—Salt solution alone=1. With polarization, 0.
Sixth irritations.—Salt solution alone=1. With polarization, 0.
Seventh irritations.—Salt solution alone=1. With polarization, 0.

EXPERIMENT 77.

Polarization current from 2 Daniels.

Eighth irritations.—Salt solution alone=1. With polarization, 0.
Ninth irritations.—Salt solution alone=1. With polarization, 0.
Tenth irritations.—Salt solution alone=1. With polarization, 0.
Eleventh irritations.—Salt solution alone=1. With polarization, 0.

EXPERIMENT 78.—Sciatic nerve and gastrocnemius muscle of a Rana esculenta.

Polarizing current from 1 Daniel cell.

First irritations.—Salt solution=3. With polarization, 5.
Second irritations.—Salt solution=3. With polarization, 5.
Third irritations.—Salt solution=3. With polarization, 5.
Fourth irritations.—Salt solution=2. With polarization, 5.
Fifth irritations.—Salt solution=2. With polarization, 5.

EXPERIMENT 79.—Sciatic nerve and gastrocnemius muscle of a Rana esculenta.

Polarization current from 4 Daniel cells.

First irritations.—Salt solution alone=0.5. With polarization, 0.
Second irritations.—Salt solution alone=1. With polarization, 3.
Third irritations.—Salt solution alone=1. With polarization, 2.
Fourth irritations.—Salt solution alone=1. With polarization, 2.

EXPERIMENT 80.—Sciatic nerve and gastrocnemius muscle of a Rana temporaria.

Polarizing current from 4 Daniel cells.

First irritations.—Salt solution alone=1. With polarization, 5.
Second irritations.—Salt solution alone=1. With polarization, 5.
Third irritations.—Salt solution alone=1. With polarization, 5.
Fourth irritations.—Salt solution alone=1. With polarization, 5.

EXPERIMENT 81.—Sciatic nerve and gastrocnemius muscle of a Rana temporaria.

Polarizing current from 1 Daniel cell.

First irritations.—Salt solution alone=1.5. With polarization, 3.
Second irritations.—Salt solution alone=1.5. With polarization, 1.5.
Third irritations.—Salt solution alone=1.5. With polarization, 1.5.

After twenty minutes:

Fourth irritations.—Salt solution alone=1. With polarization, 3.
Fifth irritations.—Salt solution alone=1. With polarization, 3.
Sixth irritations.—Salt solution alone=1. With polarization, 3.
Seventh irritations.—Salt solution alone=0.5. With polarization, 4.
Eighth irritations.—Salt solution alone=0.5. With polarization, 4.
Ninth irritations.—Salt solution alone=0.5. With polarization, 4.
Tenth irritations.—Salt solution alone=0.5. With polarization, 4.

EXPERIMENT 82.—Sciatic nerve and gastrocnemius muscle of a Rana temporaria.

Polarizing current from 4 Daniel cells.

First irritations.—Salt solution alone=1.5. With polarization, 2.
Second irritations.—Salt solution alone=1.5. With polarization, 3.
Third irritations.—Salt solution alone=1.5. With polarization, 0.
Fourth irritations.—Salt solution alone=1.5. With polarization, 0.

Fifth irritations.—Salt solution alone=1.5. With polarization, 0.5.
Sixth irritations.—Salt solution alone=1.5. With polarization, 0.5.

EXPERIMENT 83.—Sciatic nerve and gastrocnemius muscle of a Rana temporaria.

Polarizing current from 4 Daniel cells.

First irritations.—Salt solution alone=2. With polarization, 2.
Second irritations.—Salt solution alone=2. With polarization, 2.
Third irritations.—Salt solution alone=2. With polarization, 2.
Duration of experiment 13 minutes.

EXPERIMENT 84.—Sciatic nerve and gastrocnemius muscle of a Rana temporaria.

Polarizing current from 4 Daniel cells.

First irritations.—Salt solution alone=0.5. With polarization, 0.5.
Second irritations.—Salt solution alone=0.5. With polarization, 0.8.
Third irritations.—Salt solution alone=0.5. With polarization, 1.
Fourth irritations.—Salt solution alone=0.5. With polarization, 0.5.
Fifth irritations.—Salt solution alone=0.5. With polarization, 1.
Sixth irritations.—Salt solution alone=0.5. With polarization, 0.

EXPERIMENT 85.—Sciatic nerve and gastrocnemius muscle of a Rana temporaria.

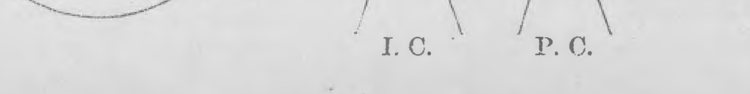
Polarizing current from 4 Daniel cells.

First irritations.—Salt solution alone=3. With polarization, 4.
Second irritations.—Salt solution alone=3. With polarization, 4.
Third irritations.—Salt solution alone=3. With polarization, 4.
Fourth irritations.—Salt solution alone=3. With polarization, 3.5.
Fifth irritations.—Salt solution alone=3. With polarization, 3.5.
Sixth irritations.—Salt solution alone=3. With polarization, 3.5.
Seventh irritations.—Salt solution alone=3. With polarization, 3.
Eighth irritations.—Salt solution alone=0. With polarization, 2.
Ninth irritations.—Salt solution alone=0. With polarization, 2.5.
Tenth irritations.—Salt solution alone=0. With polarization, 2.
Eleventh irritations.—Salt solution alone=0. With polarization, 2.

This series of experiments made with chemical irritants certainly give us no more reason to believe in the infallibility of Pflügers "laws" than the preceding series.

In finishing these series of experiments the following conclusion seems to be demanded by the facts observed: *When a descending polarizing current is applied to a nerve above a descending irritating current, the effect of the latter in exciting the nerve to produce muscular contractions is not necessarily increased during the passage of the former.* On the contrary, it often appears to be less irritating during the passage of the descending polarizing current through the nerve.

The ascending polarizing current applied to a nerve above a descending irritating current.



The irritation being here to the side of the anode, it should, according to Pflüger, produce a stronger contraction during the absence than during the presence of the constant or polarizing current. The method of experimenting adopted was that described some pages back. As there, the first experiments were made with the closing of an electric circuit as an irritant.

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
	86.			
h. m.		Irritation, 2 cells:	Polarization:	Rana temporaria.
	1st irritations...	3.	4 cells............1.	
	2d irritations....	3.	2 cells............0.	
	3d irritations....	1.5	0.	
	4th irritations...	0.5	0.	
	5th irritations...	1.	0.	
	87.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells:	Rana temporaria.
	1st irritations...	3703 cent......0.5	0.	
	2d irritations....	3703 cent......0.5	1.	
	3d irritations....	2907 cent......0.5	1.	
	4th irritations...	2675 cent......0.	0.5	
	5th irritations...	2781 cent......2.	0.	
	6th irritations...	2781 cent......1.5	2.	10 minutes later.
	7th irritations...	1214 cent ......0.	3.	
	8th irritations...	1308 cent......0.	3.	
	9th irritations...	1308 cent......0.	3.	
	10th irritations..	1308 cent......0.	3.	
	11th irritations..	223 cent......0.5	3.	
	12th irritations..	223 cent......0.5	3.	
	13th irritations..	223 cent......0.5	3.	
	88.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells:	Rana temporaria.
	1st irritations...	3109 cent......0.	0.5	
	2d irritations....	3109 cent......0.	0.5	
	3d irritations....	3109 cent......0.	0.5	
	4th irritations...	3109 cent......0.	0.5	
	89.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells:	Rana temporaria.
2 46	1st irritations ..	3109 cent......0.5	0.5	
3 05	2d irritations....	3109 cent 0.5	0.5	
10	3d irritations....	3109 cent......0.5	0.5	
13	4th irritations ..	3109 cent 0.5	0.5	
20	5th irritations ..	3109 cent 0.5	0.5	
25	6th irritations...	3109 tent......0.5	0.5	
30	7th irritations...	3109 cent......0.5	0.5	
35	8th irritations...	3109 cent......0.5	0.5	
	90.			
		Irritation, 1 cell:	Polarization, 2 cells:	Rana temporaria.
	1st irritations ..	1.	3.	
	2d irritations ...	1.	0.5	
	3d irritations ...	1.	0.5	
	91.			
		Irritation, 1 cell:	Polarization, 2 cells:	Rana temporaria
9 09	1st irritations...	1.	0.	
13	2d irritations....	1.	0.	
	92.			
		Irritation, 1 cell:	Polarization, 2 cells:	Rana temporaria.
10 05	1st irritations...	1.	0.	
07	2d irritations....	1.	3.	
11	3d irritations....	1.	3.	
40	4th irritations...	1.	3.	
11 00	5th irritations...	1.	0.5	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
	93.			
h. m.		Irritation, 1 cell:	Polarization, 2 cells:	Rana esculenta.
12 04	1st irritations...	1.	0. 5	
10	2d irritations....	1.	0. 5	
15	3d irritations....	1.	0. 5	
	94.			
		Irritation, 1 cell:	Polarization, 2 cells:	Rana temporaria.
3 08	1st irritations...	1.	0.	
14	2d irritations....	1.	0.	
19	3d irritations....	1.	0.	
4 10	4th irritations...	1.	0. 5	
	95.			
		Irritation, 1 cell:	Polarization, 2 cells:	Rana esculenta.
9 59½	1st irritations...	1.	0. 5	
10 02	2d irritations....	1.	0.	
03	3d irritations....	1.	0.	
05	4th irritations...	0.	0.	
07	5th irritations...	0.	0.	
	96.			
		Irritation, 1 cell:	Polarization:	Rana esculenta.
10 35	1st irritations...	1.	4 cells.............0.	
37	2d irritations....	1.	2 cells.............0.	
38	3d irritations ...	1.	0.	
40	4th irritations...	1.	0.	
43	5th irritations...	1.	0.	
44	6th irritations...	1.	0.	
45	7th irritations...	1.	0.	
53	8th irritations...	1.	0. 5	
11 06	9th irritations...	1.	1.	
	97.			
		Irritation, 1 cell:	Polarization, 4 cells:	Rana temporaria.
11 10	1st irritations...	1.	3.	
12	2d irritations....	1.	3.	
13	3d irritations....	1.	1.	
22	4th irritations...	1.	0. 5	
	98.			
		Irritation, 1 cell:	Polarization, 4 cells:	Rana temporaria.
11 40	1st irritations...	1.	0. 5	
47	2d irritations....	1.	0. 5	
49	3d irritations....	1.	0. 5	
	99.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana esculenta. Weak irritating currents.
2 09	1st irritations...	1.	0.	
10	2d irritations....	1.	0.	
13	3d irritations....	1.	0.	
	100.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Last frog again used. Strong irritating currents.
2 15	1st irritations...	1.	4.	
20	2d irritations....	1.	4.	
23½	3d irritations....	1.	3.	
25	4th irritations...	1.	3.	
	101.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells:	Rana temporaria.
3 42	1st irritations...	2458 cent......1.	0. 5	
45	2d irritations...	2350 cent......1.	0. 5	
48	3d irritations...	2350 cent......1.	0 5	
4 00	4th irritations...	2127 cent......0.	3.	
	102.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells:	Rana esculenta.
4 17	1st irritations...	2907 cent......0. 5	0.	
19	2d irritations....	2907 cent......0. 5	0.	
21	3d irritations....	1793 cent......1.	3.	
24	4th irritations...	2781 cent......1. 5	0.	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
	103.			
h. m.		Irritation, 1 cell, rheochord:	Polarization, 2 cells:	Rana esculenta.
4 02	1st irritations...	2562 cent......0.	0.	
06	2d irritations....	2562 cent......0.	0.	
10	3d irritations....	2249 cent......1.	0.	
13	4th irritations...	2249 cent......1.	0. 5	
16	5th irritations...	2249 cent......1.	1.	
20	6th irritations...	2249 cent......1.	1.	
30	7th irritations...	2249 cent......1.	0. 5	
35	8th irritations...	2249 cent......1.	0. 5	
	104.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells:	Rana esculenta.
5 05	1st irritations...	2781 cent......0.	3.	
13	2d irritations....	2675 cent......0.	3.	
20	3d irritations....	2458 cent......3.	2.	
23	4th irritations...	223 cent......1. 5	1.	
29	5th irritations ..	223 cent......1. 5	3.	
33	6th irritations ..	1634 cent......1.	0. 5	
35	7th irritations...	2127 cent......1.	0.	
36	8th irritations...	1634 cent......1.	0.	
37	9th irritations...	1413 cent......1.	0. 5	
37½	10th irritations..	1109 cent......1.	0. 5	
39	11th irritations..	223 cent ......1.	0. 5	
43	12th irritations..	223 cent......0.	3.	
44	13th irritations..	223 cent......1.	0.	
56	14th irritations..	223 cent......1.	0. 5	
	105.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells:	Rana esculenta.
10 06	1st irritations...	1893 cent......1.	0.	
14	2d irritations....	223 cent......1.	2. 5	
17	3d irritations ...	2016 cent......1.	0. 5	
18	4th irritations...	223 cent......1.	3.	
19	5th irritations...	1893 cent......0.	0. 5	
20	6th irritations...	1793 cent......0.	0.	
21	7th irritations...	1634 cent......0.	0.	
21½	8th irritations...	1526 cent......0.	0.	
	106.			
		Irritation, 1 cell, rheochord:	Polarization:	Rana temporaria.
10 35	1st irritations...	2955 cent......1.	4 cells...........0.	
37	2d irritations....	2955 cent......1.	1 cell............0.	
40	3d irritations....	2955 cent......0. 5	4 cells...........0.	
50	4th irritations ..	2955 cent......0.	0.	
53	5th irritations...	2401 cent......2.	2.	
55	6th irritations...	2728 cent......2.	1.	
59	7th irritations...	2728 cent......1.	0.	
11 00	8th irritations...	2728 cent......0.	0.	
12	9th irritations...	2728 cent......0.	0.	
16	10th irritations..	223 cent......1. 5	1. 5	
20	11th irritations..	2728 cent......1.	1. 5	
25	12th irritations..	2728 cent......1.	0. 5	
28	13th irritations..	2728 cent......1.	0. 5	
34	14th irritations..	2728 cent......1.	0. 5	
40	15th irritations..	2728 cent......1.	0. 5	
43	16th irritations..	2728 cent......1.	0. 5	
54	17th irritations..	2728 cent......1.	0. 5	
12 00	18th irritations..	2728 cent......1.	0. 5	
	107.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells:	Rana temporaria.
12 12	1st irritations...	223 cent......3.	3.	
19	2d irritations....	223 cent......3.	3.	
40	3d irritations....	223 cent......3.	3.	
	108.			
		Irritation, 1 cell, rheochord:	Polarization, 1 cell:	Rana temporaria.
1 05	1st irritations...	3179 cent......0.	3.	
09	2d irritations....	3198 cent......0.	3.	
11	3d irritations....	223 cent......3.	3.	
12	4th irritations...	3198 cent......0.	3.	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
h. m.				
1 37	5th irritations...	2849 cent......1.	0.	
39	6th irritations...	2[illegible]95 cent......1.	1.	
40	7th irritations...	223 cent 2. 5	2. 5	
56	8th irritations...	3194 cent......0.	2. 5	
2 05	9th irritations...	223 cent......1. 5	0. 5	
25	10th irritations..	223 cent......1.	1.	
	109.	Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana esculenta.
3 20	1st irritations...	3109 cent......0.	0.	
23	2d irritations....	1847 cent......2.	0. 5	
24	3d irritations....	1413 cent 2. 5	1.	
27	4th irritations...	223 cent......4.	4.	
	110.	Irritation, 1 cell, rheochord:	Polarization, 2 cells:	Rana temporaria.
3 40	1st irritations...	3197 cent......0.	3.	
42	2d irritations....	3197 cent......0.	4.	
43	3d irritations....	3197 cent......0.	3.	
48	4th irritations...	3197 cent......0.	2.	
50	5th irritations...	223 cent......0.	3.	
51	6th irritations...	3109 cent......0.	3.	
57	7th irritations...	1 cell ....5.	5.	
4 05	8th irritations...	1 cell..........0.	3.	
16	9th irritations...	1 cell..........3.	5.	
	111.	Irritation, 1 cell:	Polarization, 2 cells:	Rana temporaria.
4 28	1st irritations...	2.	2.	
38	2d irritations....	4.	4.	
45	3d irritations....	4.	2.	
		Rheochord:		
50	4th irritations...	1580 cent......4.	0.	
55	5th irritations...	2728 cent......0.	2.	
5 00	6th irritations...	2728 cent......1.	1.	
05	7th irritations...	2728 cent......1.	0.	
10	8th irritations...	2728 cent......2.	0.	
15	9th irritations...	2728 cent......1.	0.	
20	10th irritations..	2728 cent......1.	0. 5	
26	11th irritations..	2728 cent......1.	2.	
31	12th irritations..	2728 cent......5.	0. 5	
36	13th irritations..	2728 cent......4.	0. 5	
37	14th irritations..	2781 cent......0.	2.	
	112.	Irritation, 1 cell, rheochord:	Polarization, 2 cells:	Rana temporaria.
5 41	1st irritations...	2728 cent......3.	0.	
46	2d irritations....	2728 cent......4.		
51	3d irritations....	2781 cent......4.	0.	
56	4th irritations...	2781 cent......3.	0.	
6 01	5th irritations...	2781 cent......3.	0.	
06	6th irritations...	2781 cent......3.	0.	
13	7th irritations...	2849 cent......5.	0.	
18	8th irritations...	2849 cent......1.	0.	
20	9th irritations...	2849 cent......1.	0.	
26	10th irritations..	2849 cent......3.	0.	
	113.	Irritation, 1 cell, rheochord:	Polarization, 3 cells:	Rana temporaria.
2 35	1st irritations...	3187 cent......0.	1. 5	
3 03	2d irritations....	223 cent......5.	3.	
09	3d irritations....	1793 cent......4.	4.	
14	4th irritations...	1793 cent......3.	2.	
16	5th irritations...	2510 cent......3.	1. 5	
21	6th irritations...	2510 cent......4.	0.	
26	7th irritations...	2510 cent......2.	0.	
42	8th irritations...	2510 cent......2. 5	0.	
	114.	Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana temporaria.
8 54	1st irritations...	3109 cent......0.	2.	
9 06	2d irritations....	2183 cent......3.	0.	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
h. m.				
9 10	3d irritations....	2183 cent......0.	0.	
14	4th irritations...	2016 cent......2.	0.	
25	5th irritations...	1360 cent......3.	0.	
30	6th irritations...	1360 cent......1.	0.	
36	7th irritations...	1360 cent......0. 5	0.	
40	8th irritations...	1360 cent......0. 5	0.	
	115.	Irritation, 1 cell, rheochord:	Polarization, 3 cells:	Rana temporaria.
10 14	1st irritations...	3197 cent......0.	5.	
17	2d irritations....	3197 cent......0.	5.	
21	3d irritations....	3197 cent......0.	5.	
25	4th irritations...	3058 cent......0.	5.	
26	5th irritations...	3003 cent......5.	5.	
29	6th irritations...	3003 cent......5.	3.	
36	7th irritations...	3003 cent......4.	1.	
41	8th irritations...	3003 cent......3.	1.	
52	9th irritations...	2955 cent......2.	0.	
54½	10th irritations..	2955 cent......2.	0.	
57½	11th irritations..	2955 cent......2.	0.	
11 04½	12th irritations..	2955 cent......1.	0.	
	116.	Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana temperaria.
8 47	1st irritations...	3197 cent......0.	5.	
52	2d irritations....	3197 cent......0.	5.	
57	3d irritations....	3197 cent......0.	5.	
9 01	4th irritations...	3058 cent......1.	5.	
10	5th irritations...	3058 cent......2.	5.	
15	6th irritations...	3058 cent ......0.	4.	
23	7th irritations...	3058 cent......0. 5	2.	
28	8th irritations...	3058 cent......0. 5	1.	
33	9th irritations...	3058 cent......0. 5	1.	
36	10th irritations..	3058 cent......0.	3.	
40	11th irritations..	2955 cent......2.	4.	
	117.	Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana temporaria.
9 52	1st irritations...	2849 cent......2.	1.	
54	2d irritations....	2728 cent......4.	1.	
56	3d irritations....	2728 cent ......3.	0.	
58	4th irritations...	2350 cent......4.	3.	
10 01	5th irritations...	2350 cent......4.	1.	
03	6th irritations...	223 cent......5.	5.	
05	7th irritations...	2350 cent......4.	1.	
32	8th irritations...	2562 cent......4.	2.	
33	9th irritations...	2562 cent......4.	0.	
34	10th irritations..	2849 cent......2.	0.	
35	11th irritations..	2955 cent......0. 5	0.	
38	12th irritations..	2901 cent......2.	0.	
39	13th irritations..	2901 cent......3.	1.	
42	14th irritations..	3003 cent......2.	2.	
44	15th irritations..	3003 cent......3.	2.	
	118.	Irritation, 1 cell, rheochord:	Polarization:	Rana temporaria.
		3000 cent......0. 5	1 cell..........4.	
11 00	1st irritations...	3000 cent......0. 5	4 cells..........3.	
01	2d irritations....	3000 cent 0. 5	1 cell..........0.	
02	3d irritations....	3000 cent......0. 5	4 cells..........4.	
03	4th irritations...	3000 cent......2.	4 cells..........4.	
06	5th irritations...	3000 cent......2.	1 cell..........0.	
07	6th irritations...			
	119.	Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana temporaria.
11 12	1st irritations...	2781 cent......0.	5.	
15	2d irritations....	2675 cent......0. 5	5.	
30	3d irritations....	2675 cent......0.	5.	
31	4th irritations...	2562 cent......2.	5.	
32	5th irritations...	2562 cent......1.	5.	
40	6th irritations...	3058 cent......0.	5.	
41	7th irritations...	3003 cent......1.	5.	
46	8th irritations...	3003 cent......2.	4.	
48	9th irritations...	3003 cent......2.	4.	
53	10th irritations..	3003 cent......0.	4.	
55	11th irritations..	3003 cent......0.	5.	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
	120.	Irritation, 1 cell, rheochord:	Polarization:	Rana temporaria.
h. m.				
1 07	1st irritations...	3197 cent..... 1.	4 cells.........3.	
09	2d irritations....	3197 cent......0.5	1 cell..........0.	
10	3d irritations....	3179 cent......0.	1 cell..........0.	
15	4th irritations...	3179 cent......0.	4 cells.........4.	
20	5th irritations...	3003 cent..... 1.	1 cell..........2.	
22	6th irritations...	3003 cent......2.	3.	
28	7th irritations...	3003 cent......0.5	3.	
30	8th irritations...	3003 cent......0.5	3.	
34	9th irritations...	3003 cent......0.5	3.	
35	10th irritations..	3003 cent......0.	4.	
41	11th irritations..	3003 cent......3.	4.	
	121.	Irritation, 1 cell, rheochord:	Polarization:	Rana temporaria.
2 03	1st irritations...	3003 cent......2.	1 cell..........0.	
05	2d irritations....	1160 cent......4.	1 cell..........4.	
06	3d irritations....	1160 cent......4.	4 cells.........4.	
07	4th irritations...	341 cent......4.	4 cells.........4.	
07½	5th irritations...	341 cent......4.	1 cell..........4.	
08	6th irritations...	3003 cent......1.	1 cell..........0.	
09	7th irritations...	3003 cent......1.5	4 cells.........3.	
12	8th irritations...	3003 cent......0.5	4 cells.........2.	
13	9th irritations...	3003 cent......0.5	1 cell..........0.	
14	10th irritations..	3003 cent......4.	1 cell..........4.	
15	11th irritations..	3003 cent......4.	4 cells........ 4.	
18	12th irritations..	2950 cent......0.5	1 cell..........0.	
20	13th irritations..	700 cent......4.5	4 cells.........5.	
21	14th irritations..	700 cent......4.5	1 cell..........5.	
22	15th irritations..	2775 cent......1.	1 cell..........0.	
26	16th irritations..	2675 cent......3.	4 cells.........0.	
28	17th irritations..	2675 cent......2.	1 cell..........0.	
	122.	Irritation, 1 cell, rheochord:	Polarization, 4 cells, rheochord:	Rana temporaria.
11 29	1st irritations...	3197 cent......2.	3 cent.........5.	
31	2d irritations....	3197 cent......2.	3 cent.........5.	Polarization, 1 cell.
33	3d irritations....	3176 cent......0.	0 cent.........3.	
45	4th irritations...	3176 cent......0.	5 cent.........3.	
50	5th irritations...	3176 cent......0.	2 cent.........3.	
54	6th irritations...	2910 cent......0.5	20 cent........1.	
57	7th irritations...	2910 cent......0.	20 cent........2.	
	123.	Irritation, 1 cell, rheochord:	Polarization, 4 cells, rheochord:	Rana temporaria.
9 04	1st irritations...	3018 cent......0.	1 cent.........2.	
05	2d irritations....	3018 cent......0.	20 cent........3.	
06	3d irritations....	3018 cent......2.	20 cent........4.	
07	4th irritations...	2875 cent......0.	10 cent........1.	
10	5th irritations...	2850 cent......0.	20 cent........0.5	
	124.	Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana temporaria.
9 27	1st irritations...	1400 cent......3.	20 cent........3.	
40	2d irritations....	2125 cent......0.	20 cent........0.	
43	3d irritations....	2125 cent......0.	20 cent........0.	
	126.	Irritation, 1 cell, rheochord:	Polarization, 4 cells, rheochord:	Rana temporaria.
9 50	1st irritations...	223 cent.......1.	10 cent........1.5	
56	2d irritations....	223 cent.......0.5	10 cent........1.	
10 01	3d irritations....	223 cent.......1.	10 cent........1.5	
	127.	Irritation, 1 cell, rheochord:	Polarization, 4 cells, rheochord:	Rana temporaria.
11 00	1st irritations...	3100 cent......1.	48 cent........1.	
10	2d irritations....	3025 cent......2.	30 cent........3.	
11	3d irritations....	3025 cent......1.	30 cent........2.	
18	4th irritations...	3025 cent......0.5	30 cent........2.	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
h. m.				
11 22	5th irritations...	2950 cent......2.	30 cent........4.	
25	6th irritations...	2950 cent......2.	30 cent........2.	
28	7th irritations...	2950 cent......3.	30 cent........4.	
29	8th irritations...	2950 cent......3.	30 cent........3.	
32	9th irritations...	2950 cent......2.	30 cent........3.	
34	10th irritations..	2950 cent......2.	30 cent........2.	
40	11th irritations..	2790 cent......4.	30 cent........5.	
42	12th irritations..	2790 cent......5.	30 cent........5.	
45	13th irritations..	2875 cent......3.	30 cent........3.	
46	14th irritations..	2875 cent......3.	30 cent........3.	
48	15th irritations..	2875 cent......1.	30 cent........3.	
50	16th irritations..	2875 cent......0.	30 cent........3.	
52	17th irritations..	2730 cent......2. 5	30 cent........5.	
53	18th irritations..	2730 cent......4.	30 cent........5.	
54	19th irritations..	2730 cent......3.	30 cent........5.	
55	20th irritations..	2730 cent......3.	30 cent........5.	
57	21st irritations..	2730 cent......3.	30 cent........4. 5	
58	22d irritations...	2730 cent......3.	50 cent........5.	
12 02	23d irritations...	2730 cent......1.	50 cent........5.	
15	24th irritations..	2600 cent......5.	50 cent........1. 5	
16	25th irritations..	2700 cent......3.	50 cent........5.	
20	26th irritations..	2700 cent......3.	50 cent........3.	
25	27th irritations..	2700 cent......2. 5	50 cent........3. 5	
27	28th irritations..	2700 cent......2. 5	50 cent........3.	
30	29th irritations..	2700 cent......2. 5	50 cent........3.	
32	30th irritations..	2700 cent......2. 5	50 cent........4.	
36	31st irritations..	2700 cent......2. 5	50 cent........3.	
38	32d irritations...	2700 cent......4.	50 cent........5.	
41	33d irritations...	2700 cent......2. 5	50 cent........3.	
44	34th irritations..	2700 cent......2.	50 cent........2. 5	
54	35th irritations..	2700 cent......3.	50 cent........4. 5	
	128.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells, rheochord:	Rana temporaria.
2 58	1st irritations...	2295 cent......3.	30 cent........3.	
59	2d irritations....	2401 cent......2.	30 cent........2.	
3 00	3d irritations....	2401 cent......3.	30 cent........3.	
01	4th irritations...	2401 cent......3.	10 cent........5.	
04	5th irritations...	2675 cent......2.	10 cent........2. 5	
05	6th irritations...	2675 cent......3.	10 cent........5.	
06	7th irritations...	2781 cent......1.	10 cent........1. 5	
12	8th irritations...	2781 cent......0. 5	10 cent........0. 5	
20	9th irritations...	2458 cent......2.	10 cent........3.	
28	10th irritations..	2901 cent......0.	30 cent........1.	
	129.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells, rheochord:	Rana temporaria.
3 41	1st irritations...	2675 cent......2.	30 cent........3.	
44	2d irritations....	2675 cent......1.	10 cent........1.	
45	3d irritations....	2675 cent......0.	10 cent........2.	
55	4th irritations...	223 cent......2.	10 cent........2.	
56	5th irritations...	223 cent......2. 5	40 cent........3.	
58	6th irritations...	223 cent......3.	40 cent........3.	
	130.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells, rheochord:	Rana temporaria.
1 20	1st irritations...	2781 cent......3.	49 cent........4.	
21	2d irritations....	2901 cent......3.	49 cent........4.	
23	3d irritations....	2901 cent......2. 5	10 cent........4.	
24	4th irritations...	2901 cent......2.	10 cent........4.	
30	5th irritations...	2901 cent......3.	10 cent........3.	
34	6th irritations...	2901 cent......2.	10 cent........3.	
	131.			
		Irritation, 1 cell, rheochord:	Polarization, 4 cells, rheochord:	Rana temporaria.
9 14	1st irritations...	2955 cent......4.	38 cent........4.	
16	2d irritations....	3025 cent......3.	20 cent........3.	
19	3d irritations....	3150 cent......0.	20 cent........0.	
24½	4th irritations...	3197 cent......2.	10 cent........3.	
26½	5th irritations...	3197 cent......2.	45 cent........3.	
37	6th irritations...	3198 cent......1. 5	10 cent........2.	
39	7th irritations...	3198 cent......1.	10 cent........2.	
40	8th irritations...	3198 cent......0. 5	30 cent........1. 5	
44	9th irritations...	3198 cent......0. 5	30 cent........0. 5	
46	10th irritations..	3189 cent......0. 5	30 cent........1.	

Out of the preceding forty-five experiments twenty usually gave a decreased excitability of the nerve to the side of the anode of the constant current. In three experiments (89, 107, and 124) no effect was produced by the polarization. In one experiment (115) in the beginning an increased excitability was produced to the copper side of the constant current, and in another the result was inconstant. In twenty experiments, however, the irritating current usually or always produced an increased excitability of the nerve in the anelectrotonus portion of the nerve; *i. e.*, an effect directly opposite to that demanded by Pflüger's theory.

In the following experiments the opening instead of the closing of the irritating current is recorded:

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
h. m.	**132.**	Irritation, 2 cells:	Polarization, 4 cells:	Rana temporaria.
	1st irritations...	2.	0.5	
	2d irritations....	0.5	0.	
	3d irritations....	0.5	0.	
	4th irritations...	0.5	0.	
	5th irritations...	0.5	0.	
	133.	Irritation, 1 cell, rheochord:	Polarization, 2 cells:	Rana temporaria.
	1st irritations...	2500 cent......1.5	0.	
	2d irritations....	2100 cent......1.	0.	
	3d irritations....	2100 cent......1.	1.	
	4th irritations...	2728 cent......1.5	1.	
	5th irritations...	2728 cent......1.	0.	
	6th irritations...	1308 cent......1.5	1.	
	7th irritations...	1000 cent......1.	0.	
	134.	Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana temporaria.
	1st irritations...	3100 cent......1.	0.	
	2d irritations....	3100 cent......1.	3.	
	3d irritations....	3100 cent......0.	3.	
	4th irritations...	3100 cent......0.	3.	
	135.	Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana temporaria.
	1st irritations...	3100 cent......2.	1.	
	2d irritations....	3100 cent......0.5	1.	
	3d irritations....	3100 cent......2.	1.	
	4th irritations...	3100 cent......1.	1.	
	5th irritations...	3100 cent......1.	1.	
	6th irritations...	3000 cent......1.	1.	
	7th irritations...	3000 cent......1.	1.	
	8th irritations...	3000 cent......1.	1.	
	136.	Irritation, 1 cell:	Polarization, 4 cells:	Rana temporaria.
	1st irritations...	0.	2.	
	2d irritations....	0.	1.5	
	3d irritations....	0.	1.5	
	137.	Irritation, 1 cell:	Polarization, 4 cells:	Rana temporaria.
	1st irritations...	0.	2.	
	2d irritations....	0.5	1.	
	3d irritations....	0.5	1.	
	4th irritations...	0.5	1.	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
h. m.				
	138.	Irritation, 1 cell:	Polarization, 4 cells:	Rana temporaria.
12 30	1st irritations...	0.5	0.	
45	2d irritations....	1.	0.	
46	3d irritations....	1.	0.	
48	4th irritations...	1.	0.	
54	5th irritations...	0.5	0.	
59	6th irritations...	1.	0.	
1 17	7th irritations...	1.	0.	
	139.	Irritation, 1 cell:	Polarization, 4 cells:	Rana temporaria.
3 09	1st irritations...	1.	0.	
10	2d irritations....	1.	0.	
12	3d irritations....	0 5	0.	
14	4th irritations...	0.5	0.	
16	5th irritations...	0.5	0.	
19	6th irritations...	0.5	0.	
	140.	Irritation, 1 cell:	Polarization, 4 cells:	Rana esculenta.
4 56	1st irritations...	1.	0.	
57	2d irritations....	1.	0.	
58	3d irritations....	1.	0.	
59	4th irritations...	1.	0.	
5 03	5th irritations...	1.	0.	
05	6th irritations ..	1.	0.	
06	7th irritations...	1.	0.	
09	8th irritations...	1.	0.	
14	9th irritations...	1.5	0.5	
18	10th irritations..	1.	1.	
	141.	Irritation, 1 cell:	Polarization, 4 cells:	Rana temporaria.
	1st irritations...	1.5	1.5	
	2d irritations....	2.	4.	
	3d irritations....	3.	3.	
	4th irritations...	1.5	1.5	
	142.	Irritation, 1 cell:	Polarization, 4 cells:	Rana temporaria.
1 00	1st irritations...	1.	0.5	
05	2d irritations....	1.	0.5	
10	3d irritations....	1.	0.	
	143.	Irritation, 1 cell:	Polarization, 4 cells:	Rana temporaria.
1 20	1st irritations...	1.	0.	
24	2d irritations....	1.	0.	
27	3d irritations....	1.	0.	
	144.	Irritation, 1 cell:	Polarization, 4 cells:	Rana temporaria.
1 32	1st irritations...	0.5	0.	
36	2d irritations....	0.5	0.	
39	3d irritations....	0.5	0.	
45	4th irritations...	1.	0.	
46	5th irritations...	1.	0.	
50	6th irritations...	1.	0.	
2 05	7th irritations...	1.	0.	
15	8th irritations ..			
	145.	Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana esculenta.
11 32	1st irritations...	2781 cent......1.5	0.5	
40	2d irritations....	223 cent.......1.5	0.5	
43	3d irritations....	223 cent.......1.5	0.5	
	146.	Irritation, 1 cell, rheochord:	Polarization, 1 cell:	Rana temporaria.
11 48	1st irritations...	2955 cent......1.	5.	
50	2d irritations....	2955 cent......1.	5.	
54	3d irritations....	2955 cent......1.	4.	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
h. m.				
12 00	4th irritations...	2955 cent......0. 5	4.	
05	5th irritations...	2400 cent......0. 5	3.	
07	6th irritations...	2720 cent......3.	3.	
09	7th irritations ..	2720 cent......3.	3.	
	147.	Irritation, 1 cell, rheochord:	Polarization, 1 cell:	Rana temporaria.
12 22	1st irritations...	2700 cent......1.	0. 5	
26	2d irritations....	223 cent......4.	4.	
30	3d irritations....	2700 cent......1.	1.	
32	4th irritations...	2700 cent......1.	0. 5	
34	5th irritations...	2700 cent......1.	0. 5	
38	6th irritations...	2700 cent......1.	0.	
50	7th irritations...	2700 cent......1.	0.	
52	8th irritations...	2700 cent......1.	0.	
53	9th irritations...	2700 cent......1.	0.	
1 00	10th irritations...	2700 cent......1.	0.	
	148.	Irritation, 1 cell, rheochord:	Polarization, 1 cell:	Rana temporaria.
2 20	1st irritations...	3170 cent......0.	4.	
25	2d irritations....	3199 cent...... 0.	4.	
29	3d irritations....	3199 cent......0.	4.	
32	4th irritations...	223 cent......4.	4.	
33	5th irritations...	3199 cent......0.	4.	
35	6th irritations...	3199 cent......0.	4.	
45	7th irritations...	3199 cent......0.	4.	
47	8th irritations...	3199 cent......0.	4.	
49	9th irritations...	3199 cent......0.	4.	
50	10th irritations..	223 cent......4.	4.	
3 00	11th irritations..	3199 cent......0.	4.	
01	12th irritations..	3199 cent......0.	3.	
10	13th irritations..	3199 cent......0.	3.	
11	14th irritations..	223 cent......3.	2.	
	149.	Irritation, 1 cell, rheochord:	Polarization, 4 cells:	Rana temporaria.
3 40	1st irritations...	3198 cent......3.	0.	
42	2d irritations....	3198 cent......2.	0.	
	150.	Irritation, 1 cell, rheochord:	Polarization, 1 cell:	Rana temporaria.
4 00	1st irritations...	3198 cent......0.	1.	
04	2d irritations....	3198 cent......0.	3.	
10	3d irritations....	3198 cent......0.	4.	
15	4th irritations...	3177 cent ......0.	1.	
20	5th irritations...	223 cent......4.	4.	
35	6th irritations...	3177 cent......0.	2.	
39	7th irritations ..	3169 cent......0.	2.	
41	8th irritations ..	3169 cent......0.	0. 5	
5 06	9th irritations...	2510 cent......0.	3.	
	151.	Irritation, 1 cell, rheochord:	Polarization, 3 cells:	Rana temporaria.
9 15	1st irritations...	1070 cent......3.	2.	
20	2d irritations....	1070 cent......1.	0. 5	
25	3d irritations....	1360 cent......0. 5	0. 5	
35	4th irritations...	1360 cent......0. 5	0. 5	
	152.	Irritation, 1 cell, rheochord:	Polarization, 3 cells:	Rana temporaria.
9 54	1st irritations...	3000 cent......3.	5.	
55	2d irritations....	3000 cent......4.	5.	
10 01	3d irritations....	3000 cent......3.	5.	
05	4th irritations...	3058 cent......0.	5.	
12	5th irritations...	3058 cent......0.	4.	
14	6th irritations...	2950 cent......2.	4.	
18	7th irritations...	2950 cent......2.	4.	
25	8th irritations...	2950 cent......0.	4.	
27	9th irritations...	2950 cent......0. 5	4.	
32	10th irritations..	2950 cent......0.	4.	
37	11th irritations..	2950 cent......0.	4.	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
h. m.	**153.**			
		Irritation, 1 cell, rheochord:	Polarization, 1 cell:	Rana temporaria.
10 52	1st irritations...	3000 cent......0.	1.	
56	2d irritations....	3000 cent......0.	1.	
57	3d irritations....	3000 cent......0.	2.	
	154.			
		Irritation, 1 cell, rheochord:	Polarization, 1 cell:	Rana temporaria.
11 06	1st irritations ..	3000 cent......0.	1.	
13	2d irritations....	3000 cent......0.	1.	
18	3d irritations....	3000 cent......0.	0. 5	
	155.			
		Irritation, 1 cell, rheochord:	Polarization, 1 cell:	Rana temporaria.
1 57	1st irritations...	3198 cent......0.	1.	
59	2d irritations....	3179 cent......0.	1.	
2 07	3d irritations....	3179 cent......0.	2.	
10	4th irritations...	3000 cent......0.	4.	
12	5th irritations...	3000 cent......1.	0.	Polarization, 4 cells.
20	6th irritations...	3000 cent......0.	4.	Polarization, 1 cell.
25	7th irritations...	1160 cent......0.	1.	
26	8th irritations...	341 cent......0.	1.	
27	9th irritations...	341 cent......0.	1.	
28	10th irritations..	3000 cent......0.	3.	
32	11th irritations..	3000 cent......0.	3.	
34	12th irritations..	3000 cent......0.	1.	
38	13th irritations..	2781 cent......0.	0. 5	
42	14th irritations..	2690 cent......1.	0.	
47	15th irritations..	2690 cent......1.	0. 5	
	156.			
		Irritation, 1 cell, rheochord:	Polarization, 1 cell, rheochord:	Rana temporaria.
9 12	1st irritations...	3196 cent......0.	4 cent..........3.	
15	2d irritations....	3196 cent......0.	4 cent..........3.	
18	3d irritations ...	3058 cent......0. 5	4 cent..........5.	
22	4th irritations...	3058 cent......0. 5	4 cent..........5.	
30	5th irritations...	3058 cent......0. 5	4 cent..........5.	
	157.			
		Irritation, 1 cell, rheochord:	Polarization, 1 cell, rheochord:	Rana esculenta.
2 00	1st irritations...	2900 cent......0.	18 cent 0. 5	
06	2d irritations....	2900 cent......0. 5	18 cent.........2.	
11	3d irritations....	2900 cent......0. 5	18 cent.........1.	
15	4th irritations...	2900 cent......0. 5	18 cent.........1.	
	158.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana temporaria.
2 28	1st irritations...	3050 cent......0. 5	12 cent.........0. 5	
30	2d irritations....	3050 cent......0. 5	12 cent.........0. 5	
32	3d irritations....	2900 cent......1.	12 cent.........1.	
34	4th irritations...	2900 cent......0. 5	30 cent.........3.	
35	5th irritations...	2900 cent......0. 5	30 cent.........1.	
38	6th irritations...	2675 cent......0.	30 cent.........1.	
41	7th irritations...	2675 cent......0.	30 cent.........0. 5	
44	8th irritations...	2675 cent......0.	10 cent.........3.	
	159.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana temporaria.
8 51	1st irritations...	3130 cent......0.	20 cent.........1.	
52	2d irritations....	3130 cent......0.	20 cent.........0. 5	
55	3d irritations....	3196 cent......0.	10 cent.........1.	
57	4th irritations...	3196 cent......0.	45 cent.........1.	

Out of these last twenty-eight experiments, in but eleven was the irritation less effective in producing muscular contractions during the presence of the constant current than when the irritating current alone was applied to the nerve; of the remaining experiments, in fourteen the opposite result was obtained, though the manner of experimenting was the same as adopted in the other experiments.

In the following experiments the nerves were irritated in their normal position, without having previously been injured. As in similar experiments, before described, made with the descending polarizing current, the non-polarizable electrodes had to be substituted by copper electrodes. These were covered with wax, except at the point where they touched the nerve. With this exception the apparatus was unchanged. In this series of experiments the irritation was made by the closing of a galvanic circuit.

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
h. m.	**160.**			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana esculenta.
	1st irritations...	2675 cent......0. 5	52 cent........0. 5	
	2d irritations ...	1847 cent......1.	50 cent........2.	
	3d irritations ...	1847 cent......1.	10 cent........1.	
	4th irritations...	2016 cent......1.	52 cent........1.	
	5th irritations...	2016 cent......1.	52 cent........1.	
	6th irritations...	2070 cent......1.	10 cent........0. 5	
	7th irritations...	2600 cent......0. 5	10 cent........0. 5	
	8th irritations...	2728 cent......0. 5	10 cent........0.	
	9th irritations...	2618 cent......0. 5	10 cent........0. 5	
	10th irritations..	2618 cent......0. 5	55 cent........1. 5	
	161.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana temporaria.
	1st irritations...	890 cent......1.	48 cent........0. 5	
	2d irritations ...	890 cent......1.	11 cent........1.	
	3d irritations ...	890 cent......0. 5	11 cent........2.	
	4th irritations...	890 cent......0.	49 cent........2.	
	5th irritations...	890 cent......0.	11 cent ....2.	
	6th irritations...	890 cent ......0.	10 cent........2.	
	7th irritations...	890 cent......0. 5	10 cent........0.	
	8th irritations...	890 cent......1.	49 cent........1. 5	
	162.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana temporaria.
	1st irritations...	1500 cent......0. 5	10 cent........1.	
	2d irritations ...	1800 cent......0. 5	50 cent........1.	
	3d irritations ...	1800 cent......0.	50 cent........0. 5	
	163.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana temporaria.
	1st irritations...	3000 cent......0.	25 cent........0. 5	
	2d irritations ...	3000 cent......4.	25 cent........5.	
	3d irritations ...	3000 cent......2.	25 cent........2.	
	4th irritations...	1739 cent......2.	50 cent........2.	
	5th irritations...	1739 cent......2.	50 cent........2.	
	6th irritations...	1739 cent......2.	10 cent........2.	
	7th irritations...	393 cent......2.	40 cent........4.	
	164.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana temporaria.
	1st irritations...	2500 cent......2.	52 cent........3.	
	2d irritations ...	2500 cent......2.	52 cent........4.	
	3d irritations ...	2500 cent......2.	12 cent........2.	
	4th irritations...	2100 cent......0. 5	52 cent........1.	
	165.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana temporaria.
	1st irritations...	1950 cent......2.	57 cent........2.	
	2d irritations ...	1950 cent......1. 5	57 cent........1. 5	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
h. m.				
	3d irritations ...	2675 cent......0. 2	57 cent........0. 3	
	4th irritations...	2400 cent......2.	57 cent........2.	
	5th irritations...	2400 cent......1.	57 cent........0. 5	
	6th irritations...	2300 cent......1.	57 cent........0. 5	
	7th irritations...	2300 cent......0.	57 cent........0. 5	
	8th irritations...	2300 cent......1.	57 cent........1.	
	166.	Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana temporaria.
	1st irritations...	1526 cent......0. 5	58 cent........1.	
	2d irritations ...	490 cent......2.	58 cent........4.	
	3d irritations ...	490 cent......0. 5	58 cent........0. 5	
	4th irritations...	1526 cent......0. 5	58 cent........1.	
	5th irritations...	1526 cent......0. 5	58 cent........1.	
	167.	Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana esculenta.
	1st irritations...	1725 cent......0. 5	16 cent........0. 5	
	2d irritations ...	1725 cent......0. 5	16 cent........0. 5	
	3d irritations ...	1725 cent......0. 5	16 cent........0. 5	
	4th irritations...	1725 cent......0. 5	16 cent........0. 5	
	5th irritations...	1725 cent 0. 5	16 cent........0. 5	
	6th irritations...	1725 cent......0. 5	16 cent........0. 5	
	7th irritations...	1725 cent......0. 5	16 cent....... 0. 5	
	8th irritations...	1725 cent......0. 5	16 cent........0. 5	
	9th irritations...	1725 cent......0. 5	16 cent........0. 5	
	168.	Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana temporaria.
	1st irritations...	2400 cent......1.	58 cent........2.	
	2d irritations ...	2850 cent...... 0.	58 cent........0. 5	
	3d irritations ...	2850 cent......0. 2	20 cent........0. 5	
	4th irritations...	2850 cent 0. 5	10 cent........1.	
	5th irritations...	2725 cent......0. 5	10 cent........1.	
	6th irritations...	2675 cent......0.	10 cent........1. 5	
	7th irritations...	2675 cent......0.	10 cent........1.	
	8th irritations...	26 8 cent......0.	58 cent........2.	
	9th irritations...	2618 cent......0.	58 cent........2.	
	10th irritations..	2618 cent......0.	58 cent........1. 5	

In the following experiments the irritation produced by the opening of an electric circuit is recorded:

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
	169.	Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana temporaria.
h. m.	1st irritations ...	2675 cent......1.	10 cent........2.	
	2d irritations....	2675 cent......2.	10 cent........2.	
	3d irritations....	2675 cent......1.	10 cent........0. 5	
	4th irritations...	2675 cent......0.	10 cent........0. 5	
	5th irritations...	2675 cent......0.	10 cent........0. 5	
	6th irritations...	2675 cent......0.	58 cent........2.	
	7th irritations...	2675 cent......0.	58 cent........2.	
	8th irritations...	2675 cent......0.	58 cent........2.	
	170.	Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana esculenta.
	1st irritations...	2425 cent......1.	50 cent........3.	
	2d irritations....	2728 cent......2.	50 cent........2.	
	3d irritations....	2728 cent......2.	10 cent... ....2.	
	4th irritations...	2728 cent......3.	10 cent........3.	
	5th irritations...	2728 cent......0. 5	10 cent........2.	
	6th irritations...	2728 cent......1.	10 cent........2.	
	7th irritations ..	2728 cent......0. 2	10 cent........0. 5	
	8th irritations...	2728 cent......0.	10 cent........0. 2	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
h. m.	**171.**			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana temporaria.
	1st irritations...	488 cent.......2.	55 cent........4.	
	2d irritations....	488 cent.......0.	55 cent........3.	
	3d irritations....	1525 cent.......2.	55 cent........3.	
	4th irritations...	1525 cent.......2.	55 cent........3.	
	5th irritations...	1525 cent.......2. 5	55 cent........3.	
	172.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana temporaria.
	1st irritations...	2600 cent......2.	23 cent........3.	
	2d irritations....	2600 cent......2.	23 cent........3.	
	3d irritations....	2600 cent......2.	23 cent........2. 5	
	4th irritations...	2600 cent......1. 5	23 cent........2.	
	5th irritations...	2600 cent......1.	23 cent........2.	
	173.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana temporaria.
	1st irritations...	1645 cent......0. 5	58 cent........0. 5	
	2d irritations....	1645 cent......0. 5	58 cent........0. 5	
	3d irritations....	1645 cent......0. 5	58 cent........0. 5	
	174.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana temporaria.
	1st irritations...	2605 cent......0. 5	52 cent........1.	
	2d irritations....	2605 cent......0. 5	52 cent........1.	
	3d irritations....	2605 cent......0. 5	52 cent........1.	
	4th irritations...	2605 cent......0. 5	50 cent........1. 5	
	5th irritations...	2605 cent......0. 5	50 cent........1. 5	
	6th irritations...	1825 cent......1.	50 cent........2.	
	7th irritations...	1825 cent......1.	50 cent........1.	
	8th irritations...	1825 cent......1.	50 cent........2.	
	9th irritations...	1825 cent......1.	50 cent........2.	
	10th irritations..	1825 cent......1.	50 cent........2.	
	11th irritations..	1825 cent......0. 5	50 cent........1.	
	12th irritations..	1825 cent......0. 5	50 cent ....1.	
	13th irritations..	1825 cent......0. 5	50 cent........1.	
	14th irritations..	1825 cent......0. 5	50 cent........1.	
	15th irritations..	1825 cent......0. 5	55 cent........1. 5	
	175.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana esculenta.
	1st irritations...	1526 cent......0.	45 cent........1.	
	2d irritations....	1526 cent......0.	45 cent........3.	
	3d irritations....	1526 cent......0.	45 cent........3.	
	4th irritations...	1526 cent......0.	45 cent........2.	
	5th irritations...	1526 cent......0.	45 cent........2.	
	6th irritations...	1526 cent......0.	45 cent........0. 5	
	7th irritations...	1526 cent......0.	45 cent........0. 5	
	8th irritations...	1526 cent......0.	45 cent........0. 5	
	9th irritations...	1000 cent......1.	45 cent........1. 5	
	176.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana temporaria.
	1st irritations...	900 cent........0. 5	40 cent........1. 5	
	2d irritations....	900 cent........1.	40 cent........1.	
	3d irritations....	900 cent........1.	40 cent........1.	
	4th irritations...	900 cent........1.	40 cent........0.	
	5th irritations...	900 cent........0. 5	40 cent........2.	
	6th irritations...	900 cent........2.	40 cent........2.	
	7th irritations...	900 cent........2.	40 cent........3.	
	177.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana esculenta
	1st irritations...	223 cent........1. 5	10 cent........3.	
	2d irritations....	223 cent........0. 5	10 cent........2.	
	3d irritations....	1675 cent........1.	10 cent........1.	

Time.	Number of experiment.	Irritation without polarization.	Irritation during polarization.	Remarks.
h. m.	**178.**			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana temporaria.
	1st irritations...	1500 cent......5.	58 cent........5.	
	2d irritations....	1500 cent......4.	58 cent........4.	
	3d irritations....	1500 cent......4.	58 cent........4.	
	4th irritations...	2350 cent......0. 5	40 cent........1.	
	5th irritations...	2350 cent......1.	45 cent........2. 5	
	6th irritations...	2000 cent......2.	45 cent........3.	
	179.			
		Irritation, 1 cell, rheochord:	Polarization, 2 cells, rheochord:	Rana temporaria.
	1st irritations...	3003 cent......4.	25 cent........5.	
	2d irritations....	3003 cent......2.	25 cent........3.	
	3d irritations....	3003 cent......1. 5	25 cent........1. 5	
	4th irritations...	3003 cent......1.	47 cent........3.	
	5th irritations...	3003 cent......0.	52 cent........4.	
	6th irritations...	3003 cent......0.	10 cent........3. 5	
	7th irritations...	3003 cent......0.	10 cent........1.	
	8th irritations...	3006 cent......0.	55 cent........2. 5	
	9th irritations...	3006 cent......0. 5	55 cent........2.	
	10th irritations..	3006 cent......0. 5	10 cent........1. 5	
	11th irritations..	2700 cent......1.	55 cent........3.	

Of this last series of twenty experiments not one could be used as an illustration of Pflüger's theory, and almost all of them gave results directly opposite to what is demanded by this theory. In fifteen of the experiments the polarizing current usually produced an increased excitability of the nerves.

Thus far one hundred and seventy-eight new experiments have been recorded in this paper, in but seventy-two of which was the theory of Pflüger confirmed. This result convinced me that this theory could not be true except in a modified state. For, if true, how will the directly opposite results obtained in over one-half my experiments be explained. Yet, as in so many of my experiments an increased excitability was found in the katelectrotonic portion of the nerve, or a decreased excitability in the anelectrotonic portion, I could not but believe that a grain of truth was mingled with the peck of chaff which has been given us as orthodox truth in the books of physiology under the name of "Pflüger's Laws of Electrotonus." The "grain of truth" consisted in the fact that this condition sometimes did occur, and it was therefore necessary to determine why it is not always present.

On looking more carefully over my experiments it occurred to me that *the effect of irritating a polarized nerve is influenced by the strength of the polarizing and irritating currents.* The experiments of Budge*, Munk†, and Schiff and Herzen‡ have already shown that the strengths of the currents did in some way influence the effect of the polarization on the excitability of the nerve, but no one has thought of using this fact to explain the varying results obtained by irritating a polarized nerve.

For illustrations of this fact as respects the strengths of the polarizing currents *vide* experiments 9 (irritations 2, 3, and 4), 11, 26 (irritations 27 to 32), 28 (irritations 18 to 30), 46 (irritations 3 and 4), 52 (irritations 1 and 2), 53 (irritations 1 to 5), 58, 118, 121, 160, &c.

*Loc. cit. †Loc. cit. ‡Loc. cit.

In illustration of the fact that the strength of the irritating current influences the effect of the polarizing current on the excitability of nerves *vide* experiments 12, 13, 14, 16, 22, 26, 28, 43, 127, &c.

May not the extent of muscular contractions produced by the irritation of a polarized nerve be largely due to the proportion between the strengths of the two currents?

In the first experiments made in answer to this question the irritations were made by means of an induction apparatus, the non-polarizable electrodes being, however, still adhered to. The polarizing current, whose strength was never changed, was produced by a single Leclanche cell. In these experiments I found that when the strength of irritation produced a minimal contraction—no weight being attached to the myograph—both the ascending and descending polarizing current produced an increased irritability of the nerve to the side of the anode as well as to the side of the kathode. With a somewhat stronger induction current, or, what amounted to the same thing, by attaching a weight to the myograph, and then observing the minimal contractions, the results of Pflüger were obtained; that the polarizing current produced an increased excitability of the nerve to the side of the kathode and a decreased excitability to the side of the anode. By still further increasing the strength of the irritation the results of Eckhard were obtained—a decreased excitability of the nerve to the side of the kathode as well as to the side of the anode.

Illustrative experiments.

Number of experiment.	Irritation alone.		Irritation during polarization.	Remarks.
	Strength of current.	Contraction.		
	cent.	*mm.*	*mm.*	
180.				
			Descending polarization:	Rana esculenta.
1st irritations	24.	6.5	....	In these experiments 0. cent represents the strongest possible irritation.
2d irritations	24.	......	Contraction.........13.5	
3d irritations	24.	6.4	Contraction.........13.5	
4th irritations	24.	14.	Contraction.........17.	30 minutes later.
5th irritations	24.	9.	Contraction.........14.	
181.				
			Ascending polarization:	Rana esculenta.
1st irritations	13.	10.	Contraction.........13.	
2d irritations	13.	11.9	Contraction......... 15.	
3d irritations	14.	10.1	Contraction.........11.4	
4th irritations	14.	11.	Contraction.........11.6	
5th irritations	14.5	0.	Contraction.........11.	
6th irritations	15.	0.	Contraction......... 3.5	
7th irritations	15.	0.	Contraction......... 8.6	
8th irritations	9.	9.5	Contraction......... 7.9	
9th irritations	9.	9.1	Contraction......... 5.5	
10th irritations	0.	5.5	Contraction......... 0.	
182.				
			Ascending polarization:	Rana esculenta.
1st irritations	8.	0.	....	
2d irritations	8.	.....	Contraction......... 8.6	
3d irritations	6.	5.6	....	

Illustrative experiments—Continued.

Number of experiment.	Irritation alone.		Irritation during polarization.	Remarks.
	Strength of current.	Contraction.		
	cent.	*mm.*	*mm.*	
4th irritations	6.	......	Contraction........10.	
5th irritations	6.	9.	......	
183.			Descending polarization:	Last preparation again used.
1st irritations	6.	4.	......	
2d irritations	6.	4.	Contraction........ 5.9	
3d irritations	6.	......	Contraction........ 5.9	
4th irritations	6.	6.5	......	
5th irritations	6.	......	Contraction........ 7.1	
184.			Ascending polarization:	Rana esculenta.
1st irritations	13.5	6.7	......	10 grammes weight attached.
2d irritations	13.5	......	Contraction........ 6.2	
3d irritations	8.5	6.5	......	
4th irritations	8.5	......	Contraction........ 6.1	
5th irritations	8.5	8.1	......	
6th irritations	8.5	......	Contraction........ 6.	
7th irritations	8.5	14.	......	Weight reduced to 2 grammes.
8th irritations	8.5	......	Contraction........ 8.5	
9th irritations	8.5	13.	......	
10th irritations	10.5	8.6	......	
11th irritations	10.5	......	Contraction........ 2.	
12th irritations	11.	3.5	......	
13th irritations	11.	......	Contraction........ 5.9	
14th irritations	18	3.5	......	Another portion of the nerve irritated.
15th irritations	18	......	Contraction........ 2.5	
16th irritations	18	3.	......	
17th irritations	18	......	Contraction........ 3.5	
18th irritations	18.5	2.5	......	
19th irritations	18.5	......	Contraction........ 3.5	
20th irritations	19.5	1.5	......	
21st irritations	19.5	......	Contraction........ 2.6	
22d irritations	19.5	2.	......	
23d irritations	20.	0.	......	
24th irritations	20.	......	Contraction........ 4.3	
25th irritations	20.	0.	......	
26th irritations	20.	......	Contraction........ 1.5	
27th irritations	20.	1.	......	
28th irritations	20.	......	Contraction........ 5.5	
29th irritations	8.	3.	......	Weight increased to 10 grammes.
30th irritations	8.	......	Contraction........ 2.6	
31st irritations	14.	1.	......	
32d irritations	14.	......	Contraction........ 0.2	
33d irritations	14.	2.5	......	
34th irritations	14.	......	Contraction........ 1.8	
35th irritations	14.	2.	......	
36th irritations	14.	......	Contraction........ 0.	
185.			Ascending polarization:	Rana esculenta.
1st irritations	10.5	0.	......	2 grammes weight attached to muscle.
2d irritations	10.5	......	Contraction........ 6.9	
3d irritations	10.5	0.	......	
4th irritations	9.5	1.5	......	
5th irritations	9.5	......	Contraction........ 6.8	
6th irritations	9.5	0.	......	
7th irritations	9.5	......	Contraction........ 6.8	
8th irritations	9.	0.	......	
9th irritations	9.	......	Contraction........ 3.6	
10th irritations	9.	0.	......	
11th irritations	9.	......	Contraction........ 6.5	
12th irritations	4.5	3.6	......	Weight, 10 grammes.
13th irritations	4.5	......	Contraction........ 3.6	
14th irritations	4.5	3.5	......	
15th irritations	4.5	......	Contraction........ 3.5	
16th irritations	0.	4.	......	
17th irritations	0.	......	Contraction........ 3.5	
18th irritations	0.	3.5	......	
19th irritations	0.	......	Contraction........ 2.7	
20th irritations	0.	3.3	......	

The next series of experiments was made with the assistance of the apparatus before described, with the addition of a Marey myograph to write the strength of the contractions. The results obtained were similar to those obtained when the irritations were made by means of the induced current. The supposition that the effect of a constant current on the excitability of the nerves can be modified by changing the strength of the irritation employed being settled in the affirmative, it seemed very probable that a change in the strength of the polarizing current could produce a similar effect. This was also found to be so in a long series of experiments. It was also determined that the effect of a polarizing current may change after a varying period of time, so that it will take a stronger current (the irritation remaining the same) to cause the same relation to be produced between the contractions from the irritation of the non-polarized and polarized nerves as was produced in an earlier stage of the experiment.

A few of these experiments are here given as illustrations. They, I think, will set this vexed question in nervous physiology at rest. For, as results from these experiments, the excitability of a polarized nerve can be increased or decreased at will, not only by changing the direction of the current, but also by changing the intensities of the currents, these two facts must in conjunction form a law.

The excitability of a polarized nerve is determined by the proportion existing between the strengths of the polarizing and irritating currents. With certain proportions of the strengths of these currents the excitability of the anelectrotonic portion of the nerve is reversely influenced from that of the katelectrotonic portion.

EXPERIMENT 186.

Irritation alone.		Irritation plus polarization.		Remarks.
Strength of the irritation.	Height of the contractions.	Strength of the constant current.	Height of the contractions.	
	mm.	*cent.*	*mm.*	
		1 Daniel:		
1 small Daniel	6.	Rheochord 38	6.2	An ascending polarizing current applied 6mm above a descending irritating current.
	5.4	......do 38	6.2	
	6.4	......do 38	24.6	
	19.5	......do 38	21.2	
	6.1	......do 38	22.8	
	5.8	......do 33	14.2	
	6.	......do 33	22.1	
	13.8	......do 33	20.2	
	4.8	......do 48	21.4	
	6.6	......do 48	20.8	
	6.4	......do 48	21.3	
	20.2	......do 53	6.2	
	19.2	......do 53	16.6	
	12.2	......do 53	6.2	
	14.8	......do 33	20.6	
	13.9	......do 33	15.4	
	13.5	......do 33	14.1	
	12.1	......do 33	15.8	
	14.8	......do 56	14.8	
	16.	......do 56	14.3	
	9.	......do 56	14.2	
	13.8	......do 56	10.8	
1 cell	12.8	1 cell	1.9	
	12.6	do	4.2	
	13.3	do	2.8	
	13.	do	3.1	

In the above experiment the descending irritating current was kept of the same strength throughout. In the beginning, while the ascending polarizing current was weak, it produced an increased excitability of the nerve. When, however, it was increased to "rheochord 53," Pflüger's result (*i. e.*, a diminished excitability) was obtained, which became more marked when the polarizing current was increased to 1 cell. A curious phenomenon was observed which is to be seen, to a greater or less degree, in all the experiments. In the beginning "rheochord 33" produced an increased excitability of the nerve, while thirteen irritations later it produced the opposite effect. So it must be concluded that the preparation becoming older causes the effect of a polarizing current of a certain strength on the excitability of the nerve to change. This will explain the result obtained by Schiff and Herzen. These investigators found that while in the beginning of an experiment on the excitability of polarized nerves they might obtain certain results, 15 or 30 minutes later entirely different results were obtained.

EXPERIMENT 187.

Irritation alone.		Irritation plus polarization.		
Strength of the irritation.	Height of the contractions.	Strength of the constant current.	Height of the contractions.	Remarks.
cent.	*mm.*	*cent.*	*mm.*	
		1 Daniel cell:		
1 Daniel	16.1	Rheochord...........38	29.2	A descending polarising current 8mm. above a descending irritating current.
Rheochord........... 691	8.8		28.4	
	5.5		14.4	
	17.3		24.3	
	5.5		11.	Rana temporaria
	12.2		14.5	
Rheochord..........1308	3.8		3.8	
	3.8		3.8	
	3.8		3.8	
Rheochord..........1214	4.2		0.	
	2.1		0.	
	5.1		0.	
Rheochord..........1009	1.6		0.	
	10.1		0.	
	7.2		0.	
	8.2		4.9	
1 Daniel	18.9	1 Daniel	10.2	
Rheochord.......... 188	16.1	Rheochord...........38	12.6	
1 Daniel	9.	Rheochord.......... 33	8.2	
	15.5		15.9	
	8.2		26.2	
	12.1		25.1	
	21.	Rheochord...........38	8.2	
	31.1		8.2	
	10.		8.2	
	14.9		9.2	
2 Daniel cells	0.		7.8	
	22.2		14.1	
	16.5		7.5	
	33.5		31.	
	37.		7.2	
	7.2	Rheochord...........48	10.3	
	12.1		12.1	
	29.4		14.3	
	28.6		14.1	
	6.7	Rheochord...........56	22.1	
	6.4		7.6	
	3.2		13.4	
	11.1		8.	
	3.2		3.5	
1 Daniel	29.9	1 Daniel................	6.3	
Rheochord..........1009	29.	Rheochord.......... 38	0.	
	8.		0.	
	4.4		0.	

EXPERIMENT 187—Continued.

Irritation alone.		Irritation plus polarization.		Remarks.
Strength of the irritation.	Height of the contractions.	Strength of the constant current.	Height of the contractions.	
cent.	*mm.*	*cent.*	*mm.*	
Rheochord 789	3.2		8.9	
	2 6		10.3	
	5.5		11.8	
	4.		13.1	
	5.1		8.3	
Rheochord 691	5.		19.6	
	5.8		11.2	
	2.		4.5	
	10.1		11.6	
	0.		4.	
	0.		3.5	
Rheochord 488	4.		4.	
	3.6		3.4	
	3.6		3.4	
	7.2		4.	
Rheochord 223	4.5		4.	
	4.8		4.	
	4.		4.	
Rheochord 188	8.7		3.8	
	9.5		7.9	
2 Daniels	3.2	1 Daniel	3.2	
	3.2	Rheochord 53	3.2	
	10.1	Rheochord 48	3.4	
	13.3		3.	
	7.2		3.1	
1 Daniel	3.1		7.4	
	3.		7.1	
	3.		7.2	
	2.5	Rheochord 50	7.	
	2.1		7.2	
	2.		12.	

In this experiment a descending polarizing current of a given strength (1 Daniel cell, "rheochord 38"), and an irritating current from 1 Daniel, "rheochord 691," produced an increased excitability of the nerve to the side of the kathode (Pflüger's result.) But when the irritating current was reduced in strength to 1 Daniel, "rheochord 1308," the influence of the polarizing current on the excitability of the nerve was annihilated, and we had the same contraction resulting from the irritation alone as from the irritation and polarization in conjunction. With the irritating current somewhat stronger (1 Daniel, "rheochord 1214," and "rheochord 1009"), the polarizing current absolutely paralyzed the effect of the irritating current. Increasing this latter current still more, the polarization had a varying influence on the effect of the irritation. When, however, the polarizing current was now decreased in strength (to 1 Daniel, "rheochord 56"),the polarizing current again caused the nerve to become more excitable. The same effect was attained with the former polarization current ("rheochord 38") by using an irritating current of 1 Daniel, "rheochord 789" or "rheochord 691." With a stronger irritating current the polarized nerve was less excitable than the nonpolarized nerve. This corresponds to the result obtainedby Nobili, Matteucci, Valentin, and Eckhard, who always employed comparatively strong currents. Using a polarizing current of 1 Daniel, "rheochord 48," or "rheochord 50" strength, with the irritation of 1 or 2 Daniel cells, the former always increased the excitability of the nerve.

EXPERIMENT 188.

Irritation alone.		Irritation with polarization.		Remarks.
Strength of the contraction.	Height of the contractions.	Strength of the constant current.	Height of the contractions.	
cent.	*mm.*	*cent.*	*mm.*	
2 Daniels	3.5	1 Daniel	1.4	An ascending polarizing current above a descending irritating current.
Rheochord..........1413	5.	Rheochord...........53	4.8	
	10.		0.	
	12.5		0.	
	4.7		6.	Descending polarization.
	0.		4.	
	3.1		4.	
	3.7		5.	
	4.9	Rheochord...........57	4.9	
	4.9		4.9	
	4.9		4.9	
	5.	1 Daniel	10.2	Ascending polarization.
	5.2	Rheochord........... 6	8.4	
	5.4		7.5	
	6.5		9.5	Descending polarization.
	4.		5.6	
	5.4		9.4	
1 Daniel	1.2	Rheochord...........10	1.5	Ascending polarization.
Rheochord..........1109	1.1		1.6	
	1.5		1.6	
	1.1		0.	
	1.3		0.	Descending polarization.
	1.5		0.	
	2.5	3 Daniels	0.	
	2.1		0.6	
	1.9		0.	
	2.6		0.	Descending polarization.
	3.1		0.	
	2.5		0.	
	1.3	2 Daniels	0.	
	2.4		0.	
	1.8		0.	
	1.	1 Daniel	4.5	
	1.		4.4	
	3.5		4.7	

In experiment 188, with a descending irritating current of 2 Daniel cells, "rheochord 1413," an ascending polarizing current, Daniel, "rheochord 53" usually produced a decreased excitability of the nerve. With a descending polarizing current of the same strength the opposite effect was obtained. Increasing this current to "rheochord 57," it failed to influence the effect of the irritation. A polarizing current of 1 Daniel, "rheochord 6," passing in either direction, increased the excitability of the nerve. With an irritating current derived from 1 Daniel, "rheochord 1109," an ascending polarizing current from 1 Daniel, "rheochord 10," still slightly increased the excitability. When with the same strength of currents the polarization was descending, this latter always abolished the effect of the irritation. The latter effect always occurred when the polarizing current was increased to 2 or 3 Daniels. When but 1 Daniel was used for the descending polarization, this produced increased excitability of the nerve.

EXPERIMENT 189.

Irritation alone.		Irritation with polarization.		Observations.
Strength of the irritation.	Height of the contractions.	Strength of the constant current.	Height of the contractions.	
	mm.	*cent.*	*mm.*	
1 Daniel	3.2	1 Daniel: Rheochord...........57	5.1	Descending polarizing current.
	4.8		7.3	
	4.2		7.	Descending irritating current.
	5.1	Rheochord...........48	5.1	
	5.1		5.1	Rana temporaria.
	5.1		5.	
	9.	Rheochord...........43	5.8	
	10.1		6.	
	10.1		4.9	
	11.9		5.	
	7.1		3.5	Descending polarizing current.
	8.		6.1	
	9.1		6.1	
	9.2		7.3	
	3.	Rheochord.......... 28	3.4	
	5.		7.8	
	0.		7.2	
	4.		7.1	
	1.9		7.8	
	7.		5.5	Ascending polarizing current.
	7.1		6.2	
	7.6		6.6	
	7.8		0.	
	7.		0.	
	8.9		1.4	
	7.		6.1	
	7.2		5.9	
	7.3	Rheochord...........18	7.3	Descending polarizing current.
	6.		6.	
	6.		6.	
	6.		6.	
	6.		6.	
	7.1		5.2	Ascending polarizing current.
	5.3		3.1	
	6.2		5.	
	7.	Rheochord............8	5.9	
	6.1		6.1	
	4.5		0.6	
	5.		1.9	
	5.1		2.4	
	0.4		7.	Descending polarizing current.
	0.		4.3	
	0.5		7.9	
	0.3		5.8	
	3.1	2 Daniels	0.	
	4.2		0.	
	3.1		0.	
	4.2		0.5	Ascending polarizing current.
	4.5		0.6	
	4.4		0.5	
	1.5	Rheochord............8	0.	
	4.2		0.	
	3.1		1.2	
	0.		3.	Descending polarizing current.
	0.		4.	
	0.		2.8	

In experiment 189 the descending irritating current was kept of the same strength (1 Daniel cell) throughout the experiment. With descending polarization, 1 Daniel, "rheochord 57," the excitability of the nerve was increased. With 1 Daniel, "rheochord 48," the excitability remained unaffected. Further increasing the strength of the polarizing current to "rheochord 28," an increased excitability is produced for the descending current and increased for the ascending. On increasing it still further to "rheochord 18," the excitability of the nerve remained uninfluenced by the descending constant current. A polarizing current of still greater strength diminished the excitability of the nerve.

EXPERIMENT No. 190.

Irritation alone.		Irritation with polarization.		Observations.
Strength of the irritation.	Height of the contractions.	Strength of the constant current.	Height of the contractions.	
cent.	*mm.*	*cent.*	*mm.*	
		1 Daniel:		
2 Daniels	16.7	Rheochord..........55	9.8	Ascending polarizing current.
	15.9		11.7	
	16		15.4	Descending irritating current.
1 Daniel:				
Rheochord..........1261	9.		0.	
	11.2		0.	Rana temporaria.
	11.8		10.8	
	11.3		10.4	
	9.		11.2	Descending polarizing current.
	8.2		9.1	
	7.5		9.2	
	10.8	Rheochord..........53	11.6	
	0.		14.1	
	0.		7.4	
	0.		6.	
Rheochord..........1059	10.2		7.3	
	6.2		6.2	
	10.		12.1	
	10.1		10.	
	10.1		7.2	Ascending polarizing current.
	10.8		7.6	
	9.3		6.1	
	10.1		1.5	
	5.2		0.	
	1.4		0.	
	0.9		0.	
	5.		8.9	Descending polarizing current.
	4.1		5.3	
	0.7		1.2	
	1.9		8.1	
Rheochord.......... 440	0.	Rheochord..........43	1.	Ascending polarizing current.
	0.		8.8	
	0.		4.4	
	3.1		8.9	
	0.3		8.1	
	1.		7.4	
	2.	Rheochord.......... 56	1.9	
	2.		0.9	
	2.		0.	
2 Daniels:				
Rheochord.......... 223	5.4		1.2	
	1.8		1.	
	1.		0.	
1 Daniel	9.	Rheochord..........38	9.	
	8.1		8.1	
	9.1		9.	
	3.		6.9	
	4.1		7.6	
	3.4		8.4	
	9.1	Rheochord..........43	5.	
	10.6		4.1	
	10.2		4.	
	4.	Rheochord..........38	7.2	
	5.1		6.1	
	5.5	Rheochord..........33	6.	
	3.2		5.1	
	3.2		5.1	
	3.1		5.	
	3.2	Rheochord..........23	7.1	
	2.1		6.9	
	3.9			
	4.9	Rheochord..........13	5.6	
	4.7		5.1	
	4.5		5.6	
	4.1		5.7	
	4.8	Rheochord.......... 4	4.8	
	4.8		4.8	
	4.8		4.8	
	4.5	1 Daniel	6.4	
	4.2		7.5	
	2.9		4.2	
	4.8	2 Daniels	4.	
	4.8		4.9	
	3.6		4.5	

EXPERIMENT No. 190—Continued.

Irritation alone.		Irritation with polarization.		Observations.
Strength of the irritation.	Height of the contractions.	Strength of the constant current.	Height of the contractions.	
cent.	*mm.*	*cent.*	*mm.*	
	4.5	3 Daniels	0.	
	4.2		0.	
	6.		0.	
	5.1		0.	
	1.5	Rheochord............43	6.9	
	1.5		5.	
	2.4		5.8	
	4.	Rhéochord...........38	3.2	
	6.1		0.	
	3.4		0.	
	4.		0.	

In the preceding experiment descending irritating currents with both ascending and descending polarizing currents were used. When an ascending polarizing current from 1 Daniel, "rheochord 55," and irritating currents from 2 Daniels or 1 Daniel, "rheochord 1261," were used, the effect of the irritation was diminished by the polarization. With the same strengths of currents, but with a descending instead of an ascending polarizing current, the opposite effect was produced. That is, under these circumstances there was diminished excitability in the anelectrotonic and increased excitability of the nerve in the katelectrotonic phase—Pflüger's result. When, now, this irritating current was increased to 1 Daniel, "rheochord 1059," both the descending and ascending polarizing currents diminished the excitability of the nerve. After some minutes, however, with the same currents, augmented excitability occurred in the katelectrotonic phase. With polarization, 1 Daniel, "rheochord 43," and irritation, 1 Daniel, "rheochord 440," the ascending polarizing current produced an increased excitability. Decreasing the strength of the polarizing current to 1 Daniel, "rheochord 56," the opposite effect was produced. With an irritating current from 1 Daniel cell, an ascending polarizing current from 1 Daniel, "rheochord 38," at first fails to affect the excitability of the nerve, but later increases it. With the same irritation, a polarizing current from 1 Daniel, "rheochord 43," produces an increased excitability of the nerve. The irritation being the same, an ascending polarizing current from 1 Daniel, "rheochord 4," does not in the least affect the excitability of the nerve. With a polarizing current from 1 Daniel and an irritating current of the same strength, the effect of the latter is increased during the presence of the former. The effect of the same irritating current is, however, absolutely annihilated by an ascending polarizing current from 3 Daniel cells. After this it was found that the effect of an irritation (1 Daniel) was increased by an ascending polarizing current from 1 Daniel, "rheochord 43," which earlier in the experiment had the opposite effect. The very opposite result was obtained with irritation, 1 Daniel, and polarization, 1 Daniel, "rheochord 38."

EXPERIMENT 191.

Irritation alone.		Irritation with polarization.		Remarks.
Strength of the irritation.	Height of the contractions.	Strength of the constant current.	Height of the contractions.	
	mm.	*cent.*	*mm.*	
1 Daniel	7.	1 Daniel: Rheochord 56	7.	Rana esculenta. Descending irritating current applied to the nerve below an ascending polarizing current.
	7.		7.	
	7.1		7.1	
	7.		7.	
	7.		7.	
	5.6	53	1.2	
	4.		1.9	
	4.		0.	
	6.1		0.	
	10.2		7.	
	7.6		2.	
	9.4		0.8	
	6.9		0.	
	7.3	48	6.2	
	6.1		0.	
	5.9		0.	
	4.5		0.	
	6.3		0.	
	0.	43	5.8	
	0.		5.9	
	0.		5.4	
	4.8		5.	
	0.		5.3	
	0.		5.4	
	0.		1.7	
	0.		7.4	
	4.2		13.4	
	3.6	38	13.6	
	2.4		10.3	
	0.	28	5.2	
	0.		4.8	
	0.		5.3	
	0.	18	1.	
	0.		0.9	
	0.		1.2	
	1.8		5.2	
	2.5	8	4.2	
	3.4		4.2	
	4.2		5.	
	2.1	4	0.	
	1.8		0.	
	3.2		0.	
	2.2		0.	
	6.4		2.3	
	1.	18	1.4	
	3.		4.1	
	1.2		10.1	
	2.		4.5	
	3.1	4	3.2	
	2.		2.8	
	3.1		3.2	
	4.	1 Daniel	0.	
	1.2		0.	
	0.8		0.	
	0.5		0.	
	2.4		0.	
	4.1	2 Daniels	3.9	
	4.1		2.8	
	7.2		3.3	
	1.		0.	
	1.		0.	
	5.4	3 Daniels	0.	
	1.2		0.	
	1.8	4 Daniels	0.	
	1.8		0.	
	2.7	6 Daniels	0.	
	2.8		0.	
	0.	1 Daniel	5.2	
	1.4		7.3	
	3.4	Rheochord..........18	5.1	
	2.2		7.1	
	2.4		4.	

The polarizing current used in the preceding experiment passed in an ascending direction, while a descending irritating current was applied to the nerve below it. When the former was of the strength of 1 Daniel, "rheochord 56," it failed to influence the effect of an irritating current derived from 1 Daniel cell. When, however, the strength of the former current was increased to "rheochord" 53 or 48, it produced a diminished excitability of the nerve; but with "rheochord" 43, 38, 28, 18, or 8, the opposite effect was produced. With "rheochord 4" a diminished excitability was produced. The same result was obtained when the polarizing current was increased to 1, 2, 3, 4, or 6 Daniels. A polarizing current of 1 Daniel, "rheochord 18," again produced an augmented excitability of the nerve.

EXPERIMENT 192.

Irritation alone.		Irritation with polarization.		Remarks.
Strength of the irritation.	Height of the contractions.	Strength of the constant current.	Height of the contractions.	
	mm.	cent.	mm.	
1 Daniel	5. 8	1 Daniel: Rheochord.......... 3	5. 8	Rana temporaria. A descending irritating current applied to the sciatic nerve below a descending polarizing current.
	5. 8		5. 8	
	5. 8		5. 8	
	5. 8		5. 8	
	5. 8		6. 9	
	4. 4	2 Daniels	0.	
	3 7	1 Daniel:	0.	
	0.	Rheochord.......... 38	6. 2	
	0.		4. 2	
	3. 9		4. 2	
	3. 5	1 Daniel:	5.	
	4. 2	Rheochord 28	4. 4	
	4.		4. 2	
	0. 4		4.	
	4.		4.	
	3. 9	23	3. 9	
	2. 2		3. 8	
	3. 3		2. 4	
	3. 4	48	3.	
	2. 8		2. 8	
	3.		3.	
	5.	Rheochord...........18	2. 6	
	1. 5		0.	
	1. 5		0.	
	4. 2		0.	
	3.	8	2. 4	
	3. 1		1. 2	
	2. 9		1. 4	
	3. 2		2. 1	
	0.		3.	
	0.		1. 8	
	0.		1. 5	
	0.		4.	
	0.		2. 8	

In the foregoing experiment the descending irritating current was kept of one strength throughout the experiment. In the beginning it remained unaffected by a polarizing current from 1 Daniel, "rheochord 55," but the contractions which it produced were prevented by a polarizing current of 2 Daniels. A polarizing current of 1 Daniel, "rheochord 38," increased the excitability, while still further increasing this current to "rheochord 8" almost annihilated the effects of the irritation.

EXPERIMENT 193.

Irritation alone.		Irritation with polarization.		
Strength of the irritation.	Height of the contractions.	Strength of the constant current.	Height of the contractions.	Remarks.
	mm.	*cent.*	*mm.*	
1 Daniel:	13.1	1 Daniel: Rheochord.........56	14.9	Rana temporaria. A descending irritating current applied to the nerve below an ascending polarizing current.
	12.6		14.7	
	13.		15.9	
	13.9		14 1	
	12.8	48	14.	
	13.5		13.5	
	13.		13.5	
	13.1	43	13.1	
	13.		13.	
	14.	38	14.	
	13.4		13.5	
	13.		12.1	
	13.9	28	13.9	
	14.		13.	
	13.2		11.9	
	11.5		11.	

As a general rule, in this experiment an increased excitability of the nerve was produced of an ascending polarizing current of the anode to the side.

EXPERIMENT 194.

Irritation alone.		Irritation with polarization.		
Strength of the irritation.	Height of the contractions.	Strength of the constant current.	Height of the contractions.	Remarks.
	mm.		*mm.*	
1 Daniel	5.	1 Daniel	9.9	Rana temporaria. A descending irritating current applied to the nerve below an ascending polarizing current.
	7.4		12.5	
	7.		11.8	
1 Daniel	10.	2 Daniels	10.	Descending polarizing current.
	10.		10.	
	10.		10.	
	9.8		9.8	
1 Daniel	8.	2 Daniels	0.	Ascending polarizing current.
	7.8		0.	
	9.1		0.9	
	9.		2.4	
1 Daniel	6.9	1 Daniel	4.2	
	6.9		5.1	
	9.		7.1	
	9.1		3.	
	5.6		0.	
1 Daniel	5.1	1 Daniel	5.1	Descending polarizing current.
	5.1		5.1	
	5.1		5.1	
	5.1		0.	Ascending polarizing current.
	5.1		2.3	
	5.		1.7	

An ascending polarizing current decreased the excitability of the nerve when both currents were of the same strength (1 Daniel). A descending polarizing current failed to influence the height of the contractions when the irritating current was derived from 1 and the polarizing current from 2 Daniels, but an ascending polarizing current under these circumstances again diminished the excitability of the nerve. With each of the currents derived from 1 Daniel, the descending polarization failed to influence the height of the contractions.

EXPERIMENT 195.

Irritation alone.		Irritation with polarization.		Remarks.
Strength of the irritation.	Height of the contractions.	Strength of the constant current.	Height of the contractions.	
cent.	*mm.*	*cent.*	*mm.*	
1 Daniel: Rheochord..........1109	1.8	1 Daniel: Rheochord...........10	1.8	Rana esc[illegible]nta. A descending irritating current applied to the nerve below an ascending polarizing current.
	1.8		1.8	
	1.8		1.8	
	1.8	10	1.8	Descending polarizing current.
	1.8		1.8	
	0.2		1.	
	0.		1.	
	0.		1.	
	0.6	16	0.	Ascending polarization.
	0.7		0.	
	0.7		0.	
	0.4		0.	

An irritating current derived from 1 Daniel, "rheochord 1109," produced the same effect when the nerve was polarized in either direction with a current derived from 1 Daniel. With a current derived from 1 Daniel, "rheochord 10," the excitability of the nerve was increased to the side of the kathode. In the positive phase of a current derived from 1 Daniel, "rheochord 16," the excitability of the nerve was abolished for an irritating current derived from 1 Daniel, "rheochord 1109."

EXPERIMENT 196.

Irritation alone.		Irritation with polarization.		Remarks.
Strength of the irritation.	Height of the contractions.	Strength of the constant current.	Height of the contractions.	
	mm.	*cent.*	*mm.*	
1 Daniel: Rheochord	14.1	1 Daniel: Rheochord...........56	14.1	Rana esculenta. A descending irritating current below a descending constant current.
	14.1		14.1	
	14.1		14.1	
	5.2	55	15.5	
	12.2		10.	
	14.1		24.3	
	12.1	56	8.	
	21.2		10.9	
	12.		10.4	
	26.9		10.8	
	23.6		13.8	
	10.9		10.9	
	10.9	48	8.2	
	8.1		4.9	
	8.1		11.2	
	10.4		0.	
	4.1		0.	
	9.		0.	
	8.7	38	9.	
	1.5		10.9	
	3.6	Rheochord...........38	9.2	
	0.		7.1	
	13.9	48	3.2	
	8.1		7.9	
	8.1		7.0	
	8.6		6.4	
2 Daniels	8.	48	19.6	
	6.6		12.1	
	7.8		13.6	
	3.2		21.6	

EXPERIMENT 196—Continued.

Irritation alone.		Irritation with polarization.		Remarks.
Strength of the irritation.	Height of the contractions.	Strength of the constant current.	Height of the contractions.	
	mm.	*cent.*	*mm.*	
1 Daniel	15. 2	Rheochord 48	13. 1	
	11.		1. 2	
	3. 8		0.	
	2. 4		0.	
	4.		0.	
	0.	28	5. 5	
	2. 2		5. 3	
	3.		4. 1	
	0.	1 Daniel	0. 8	
	0.		1. 1	
	0.		1.	
		5 Daniels:		
1 Daniel	5.	Rheochord	5.	
	5.		5.	
	5.		5.	
	5.	2 Daniels	5.	
	5.		5.	
	5.		5.	
	5.		5.	
1 Daniel	0.	1 Daniel	4. 2	
	4.		12. 4	

In the preceding experiment descending irritating and descending polarizing currents were employed throughout. The results obtained were similar to those obtained in the previous experiments.

EXPERIMENT 197.

Irritation alone.		Irritation with polarization.		Remarks.
Strength of the irritation.	Height of the contractions.	Strength of the constant current.	Height of the contractions.	
cent.	*mm.*	*cent.*	*mm.*	
1 Daniel:		1 Daniel:		
Rheochord..........223	2. 5	Rheochord...........38	6.	Rana esculenta. A descending irritating current applied to the nerve below an ascending polarizing current.
	6.		10. 3	
645	2.		0.	
	1. 8		0.	
	3. 7		0.	
	2. 9		0.	
740	0. 8		2. 1	
	0.		6. 1	
	0. 6		5. 6	
	0. 8		5. 1	
838	5. 1		3. 8	
	5.		1.	
	4. 9		2. 2	
	3.		0. 4	
	2. 2		0.	
949	4.		5. 5	
	2. 2		2. 1	
	2. 1		0. 2	
	0. 8		1. 8	
	0.		3.	

EXPERIMENT 198.

Irritation alone.		Irritation with polarization.		Remarks.
Strength of the irritation.	Height of the contractions.	Strength of the constant current.	Height of the contractions.	
cent.	mm.	cent.	mm.	
2 Daniels	5.6	2 Daniels	5.6	Rana temporaria. A descending irritating current applied to the nerve below a descending polarizing current.
	5.6		5 6	
	5.6		5.6	
	9.8		5.4	Ascending polarization.
	6.5		0.	
	6.6		4.4	
	9.4		3.9	
2 Daniels	6.4	3 Daniels	1.6	
	11.0		0.	
	5.8		0.	
	6.2		0.	
	6.		5.5	Descending polarization.
	9.2		5.4	
	5.7		0.	
	5.5		0.	
	5.6		0.	
2 Daniels	5.	1 Daniel	5.	
	5.		5.	
	2.3		6.1	Weighted muscle with 3 grammes.
	2.4		5.6	
	2.		5.	
	5.1		5.	Weight removed.
2 Daniels	4.5	1 Daniel	0.	Ascending polarization.
	4.5		0.	
	4.6		0.	
	5.2		0.	
	0.5		2.7	Weighted 10 grammes.
	0.7		2.9	
	0.5		2.4	
2 Daniels	5.	3 Daniels	1.5	Removed the weight.
	4.7		2.4	
	5.1		0.	
	5.		0.	
	4.9		0.	
	4.9		0.	Descending polarization.
	4.9		0.	
	4.9		0.	
	4.9		0.	
2 Daniels	2.2	1 Daniel	4.5	
	0.		5.1	
	0.		5.	

It will be seen in this experiment that, when on one occasion diminished excitability of the nerve resulted from the application of the descending polarizating current to the nerve attached to a non-weighted muscle, increased excitability was produced when the muscle was weighted. Again, later, when ascending polarization produced "paresis" of the nerve, attaching a weight to the muscle sufficed to bring about the opposite result.

Weighting the muscle, therefore, influences the effect of polarization on the excitability of the nerve.

EXPERIMENT 199.

Irritation alone.		Irritation with polarization.		
Strength of the irritation.	Height of the contractions.	Strength of the constant current.	Height of the contractions.	Remarks.
cent.	*mm.*	*cent.*	*mm.*	
2 Daniels: Rheochord..........2127	0.	1 Daniel	8.5	Rana temporaria. A descending irritating current above an ascending polarizing current.
	0.		8.5	
1893	0.		9.5	
	0.		8.5	
1413	0.		9.5	
	0.		10.1	
	2.4		11.	
	0.		9.6	
1009	7.6		7.5	
	5.4		2.	
	10.9		0.	
	10.9		0.	
	14.		0.	
1618	0.		11.5	Descending polarization.
	0.		7.	
	0.		10.	
2 Daniels	10.5		10.5	
	10.5		10.5	
	11.	2 Daniels	7.5	
	11.2		0.	
	11.6		1.1	
	10.5		0.	
	12.		0.	
	11.		0.	Ascending polarization.
	13.9		0.	
	9.9		7.	
	9.5		6.4	
	9.		4.2	

EXPERIMENT 200.

2 Daniels	14.5	1 Daniel: Rheochord..........54	14.5	Rana temporaria. A descending irritating current below an ascending polarizing current.
	21.		20.6	
	20.6		20.6	
	11.5	48	12.	
	11.8		12.	
	12.4	54	11.9	
	12.8		11.8	
	11.9		11.9	
	12.4	48	12.4	Descending polarization.
	12.3		12.4	
	12.4		12.4	
	12.3		12.3	
	12.1		12.3	
2 Daniels	11.5	3 Daniels	0.	Ascending polarization.
	11.5		0.	
	10.9		0.	
	10.7		0.	
	8.		3.5	Descending polarization.
	8.4		3.6	
2 Daniels	8.	2 Daniels	2.5	
	9.9		8.4	
1 Daniel	10.	3 Daniels	0.	
	9.4		0.	
	10.2		0.	
	9.7		2.	
	12.		0.	Ascending polarization.
	4.5		0.	
	4.		0.	
	2.	2 Daniels	1.	Descending polarization.
	9.1		0.	
	8.7		0.	
	9.1		0.	
	9.		5.6	
	10.		0.	Ascending polarization.
	14.2		0.	
2 Daniels	9.		9.	Descending polarization.
	9.		9.	
	9.		9.	
	8.7		8.7	
	8.7		8.7	

EXPERIMENT 200—Continued.

Irritation alone.		Irritation with polarization.		Remarks.
Strength of the irritation.	Height of the contractions.	Strength of the constant current.	Height of the contractions.	
cent.	*mm.*	*cent.*	*mm.*	
	10.6	Rheochord............6	9.2	Ascending polarization.
	10.6		3.6	
	7.9		5.4	
	8.6		0.	
	10.1		0.	
	6.		8.1	Descending polarization.
	4.2		8.4	
	5.8		9.5	
	3.9		14.2	

EXPERIMENT 201.

1 Daniel	9.5	2 Daniels: Rheochord...........55	11.5	Rana temporaria. A descending irritating current applied to the nerve below an ascending polarizing current.
	10.		9.5	
	9.		9.2	
	9.		9.	
	12.		12.	
	8.5		10.6	
	8.5		9.	Descending polarization.
	8.2		10.5	
	8.2	48	8.2	Ascending polarization.
	8.2		12.	
	8.	38	8.	
	10.2		10.1	
	8.		8.	
	8.	28	8.	
	8.		8.	
	10.	23	10.4	Descending polarization.
	8.		10.4	
	8.		10.5	
	8.		8.	
	7.5	12	11.5	
	7.5		8.2	
	0.		11.6	
	0.		8.	
	0.		8.5	
	0.		8.1	
2 Daniels	7.5	2 Daniels	0.	Ascending polarization.
	5.4		0.	
	5.2		2.9	
	6.		3.6	
	6.2		0.	
	7.		7.	Descending polarization.
	7.		7.	

EXPERIMENT 202.

1 Daniel: Rheochord.........1739	3.9	1 Daniel: Rheochord............5	11.	Rana temporaria. A descending irritating and an ascending polarizing current.
	10.	18	18.5	
	10.	56	22.4	
1009	8.		10.	
	8.	8	11.	
	9.	4	9.5	
1580	0.	4	8.2	
1739	4.8	4	12.1	
1059	5.		9.8	
	8.		9.8	
	9.1		12.3	
	7.4		12.3	
1009	11.1	5	17.6	
2 Daniels	6.5	1 Daniel	9.2	
	6.5		9.2	
	2.2		6.7	
	6.8		13.	
	5.9		13.	
	5.9	2 Daniels	11.8	
	5.7		10.9	

EXPERIMENT 202—Continued.

Irritation alone.		Irritation with polarization.		Remarks.
Strength of the irritation.	Height of the contractions.	Strength of the constant current.	Height of the contractions.	
cent.	*mm.*	*cent.*	*mm.*	
	10.7	3 Daniels	4.	
	8.8		4.1	
	9.2		4.1	
	11.		4.1	
	9.5		4.1	
	9.8		0.	
	4.		11.	Descending polarization.
	3.4		10.5	
	3.7		10.8	
	3.5		10.8	

EXPERIMENT 203.

1 Daniel: Rheochord 1009	11.3	3 Daniels	0.	Rana temporaria. A descending irritating and a descending polarizing current.
	10.1		0.	
	10.3		0.	
488	10.4		0.	
	10.5		0.	
	10.6		9.3	
	9.		1.	Ascending polarization.
	9.5		0.	
	8.8		0.	
	4.5		8.	Descending polarization, muscle weighted 20 grammes.
	6.4		7.3	
	0.		8.2	
	0.		4.	
	6.5	2 Daniels	10.9	Weight removed.
	6.5		11.7	
	6.7		10.9	
	6.4		10.9	
1 Daniel	6.2	2 Daniels	0.	Ascending polarization.
	5.5		0.	
	6.1		0.	
	6.		0.	
2 Daniels	4.9	1 Daniel	8.1	
Rheochord 1009	11.		13.5	
	11.2		12.5	
	11.3		12.8	
	9.8		14.9	
	12.5		19.3	
	4.5		3.1	Muscle weighted 20 grammes.
	3.		2.	
	3.		0.	
	2.5		0.	
	0.6		3.5	Weight removed.
	0.2		2.5	
3 Daniels	4.		10.8	
	9.2	18	19.7	Descending polarization.
	0.		8.5	
	0.		9.	Ascending polarization.
	0.		7.3	
	0.		7.6	

In this experiment, as in "Experiment 198," weighting the muscle greatly influenced the effect of polarization on the excitability of the nerve.

I could multiply these experiments almost indefinitely, having made upwards of 500 of them, but these few will suffice to justify the conclusions at which I have arrived. It is true that the experiments given are all made with the irritation applied peripherally from the polarization, but I have made numerous experiments where this relation was reversed which gave the same results. These may, however, be the subject of a future paper.

CONCLUSIONS.

The effect of an irritation of a polarized nerve as compared with the effect of the same irritation of the non-polarized nerve depends—

1. On the proportion between the strengths of the polarizing and irritating currents.

2. On the circumstance that the irritation is to the side of the anode or to the side of the kathode of the polarizing current.

3. On the length of time that the nerve muscle preparation has been exposed.

4. On the circumstance whether the muscle is weighted or not.

In at least two proportions of the two currents Pflüger's results can be obtained for an uncertain period of time. Another proportion reverses this effect, and gives increased excitability to the side of the anode, and a diminished excitability to the side of the kathode. Other proportions of the two currents may give an increased or a diminished excitability to the side of both poles. And, lastly, we may have the polarization failing absolutely to influence the effect of the irritation.

APPLICATION OF THE CONCLUSIONS.

The results obtained in the foregoing experiments would be of interest, even if they had but a scientific value, but their value is much enhanced by what they promise in enlightening our views on the pathology of the nervous system.

As respects diseases of the peripheral motor nerves, they open up an entirely new field of work. Every physician who has had even the least experience in electro-therapeutics must have come across cases of local motor affections of the nerves, producing a paralysis, which for a long time apparently resists all electrical treatment, when by changing the strength of the electrical current employed a cure is effected in a very short time.

Two such cases have come under my observation. In one of these the attending physican had used a constant current of very great strength, and only aggravated the existing paralysis of the arm and forearm. I advised and applied, daily, a constant current derived from but two large Daniel cells, and in less than a month the arm had almost completely recovered.

Another case occurred during my presence in Vienna. A young girl suffered from choreaic twitchings of the left hand. The application of constant currents of but slight strength to the brachial plexus increased these twitchings. When the current was increased in strength the twitchings ceased, and ultimately the patient was cured.

With the sensory nerves similar phenomena can be observed. A person strikes his head (or some other portion of his body) against a hard object, and as a result a sensation of pain remains. Now, applying a constant pressure to the injured part will increase, decrease, or even abolish the pain according to the degree of pressure. Applying the constant pressure to other portions of the body will oftentimes relieve or increase the pain. Under these circumstances the constant current is replaced by the pressure.

The experiments are again of importance in explaining the varying symptoms following a hemorrhage into a given portion of the brain, and also in explaining why a lesion in the neighborhood of the corpus striatum in man should produce hemiplegia of the opposite limbs, while its destruction in man or any of the mammals is never followed by this symptom. Again, it will explain why we have sometimes paralysis and at other times convulsions, or in still other cases paralysis and convulsions in the same person from the same brain lesion.

The fact that cerebral-hemiplegia had never been produced in animals attracted my attention four years ago. Since that time I have constantly endeavored to produce this symptom in animals, but until recently with no success.

After having found that section of the whole brain immediately above the corpora quadrigemina is not followed by abolition of the voluntary movements,* it occurred to me that perhaps Brown-Sequard's theory was the true one, and that the paralysis resulting from brain lesions was due to the irritation and not to the destruction of the nerve tubules in this organ. If this be so, an irritating substance injected into the brain in the vicinity of the corpus striatum would produce paralysis of the opposite side of the body. I tried this by injecting aqua ammonia, but in the first experiments injected too much, and the animals died in convulsions or coma. Later, by using an injection of 1–3*m*, I was, in several dogs and cats, able to produce hemiplegia on the side opposite to that on which the injection was made. The animals, in attempting to walk, dragged their limbs as in true hemiplegia. Even in them, however, under unusual strong excitement, the paralyzed limbs were moved.† This result could not have been due to pressure on distant parts, as the injection of a similar quantity of water failed to produce the same effect.

These experiments with ammonia were sufficient to show that hemiplegia can be produced in animals by the injection of irritating substances in the neighborhood of the corpus striatum. The same effect

*A most interesting case is reported by Dr. Harlow (Boston Medical and Surgical Journal, December 13, 1848), in which the portions of the brain frequently considered as presiding over volitional movements were destroyed by a tamping-iron being driven through the skull. The patient lived many years after the injury was received. No signs of paralysis were manifest.

Another case is reported by Dr. Folsom (Pacific Medical and Surgical Journal, May, 1869), where a longitudinal hemi-section of the brain, extending nearly, if not quite, to the base of this organ, was made by the patient falling against a circular-saw revolving about two thousand times a minute. The man recovered without paralysis.

† Carpenter (Physiology, 1855, note on page 635) reports similar phenomena occuring in a man. Abercrombie (On the Brain), Wicke (Die Grossen Veits-Tanzele), and other authors report similar cases.

was produced when a solution of the glucoside saponin was substituted for the ammonia. With these substances hemiplegia was not always produced, though the injection was made into the same portion of the brain. In some cases a sort of hemi-chorea, and in others general convulsions, were produced.

From these experiments we must believe that hemiplegia results from an irritation (or polarization?) and not from the destruction of motor centres. How are these, the varying results following irritation of the same part of the brain, to be explained?

Ammonia or saponin applied to a nerve tubule* really acts by polarizing this structure. The impulse causing the animal to make volitional movements comes from the peripheral centres, and is no doubt similar to an irritation in its effects on the central nerve tubules. Now, it was seen that in a polarized nerve the effect of the irritating current is increased or decreased as the relation between the proportions of the two currents is changed. A polarizing current of a certain strength applied to the fibres in the vicinity of the corpus striatum will diminish or totally "inhibit" an ordinary volitional impulse;† but when we increase the strength of this irritation or impulse, as we undoubtedly do under strong excitement, other proportions between the two currents result, and consequently we have other effects.

Again, under other circumstances a lesion of the same portion of the brain will produce convulsions. Here we have the proportions between the strengths of the two currents again changed. The polarizing current now increases instead of decreases the effect of the irritating current.

In conclusion, I would say that the reason why a lesion in the same portion of the brain at one time produces paralysis, at another has no effect, and in a third instance produces convulsions (or tremors), is to be found in the proportion, which exists in each individual case, between the current developed in the nerve tubule by the lesion and that which proceeds from the peripheral centres in the production of volitional impulses.

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*A nerve tubule undoubtedly has the same properties whether it be of intercentral or peripheral significance.

†A hemiplegic person has the will to move the paralysed limbs, but not the power.

RESEARCHES UPON FEVER.

By H. C. Wood, Jr., M. D., *of Philadelphia.*

The following is a brief analysis of the argument and results, so far as reached, of the researches upon fever, which have occupied my attention for some years, and towards which the Smithsonian Institution has so liberally contributed pecuniary aid. This article, however, affords nothing more than the barest outline of the work done; many minor points and discovered facts are altogether omitted, and no allusion is made to the work of other persons. The extended memoir awaiting publication by the Institution will contain all necessary historical matters and any proper acknowledgment of previous investigations. It may be allowable here to state that, except in the chemical section, showing the agreement between my results on heat production and studies on the same subject, made by calculating ingesta and egesta, no experimental results previously arrived at by other observers have been accepted without thorough repetition and verification.

The first effort, naturally, was to determine if fever be as complex as it seems, or whether there be not some dominant symptom which is the characteristic one of the process. By artificially heating living animals both throughout the whole body and in local regions, such as the head, it was clearly shown that elevation of the bodily temperature is sufficient to produce all the nervous and circulatory symptoms of fever, and that the cooling of the heated part is capable of removing the symptoms. Parallel experiments made upon man in simple thermic and other fevers gave parallel results to those reached in the lower animals, and warrant the conclusion that the dominant symptom of fever is the excessive bodily temperature. Fever may therefore be defined to be a morbid process which produces elevation of the bodily temperature. The question that naturally presents itself at this point is—Is the increase of the bodily temperature due to an increase of the amount of heat produced, or is it caused by a failure of the body to throw off its heat? As, however, the study of normal physiology naturally precedes that of morbid physiology, and as our knowledge of the methods in which nature regulates the production and evolution of bodily heat is very scanty, it seemed proper before proceeding farther with the researches upon fever to endeavor to elucidate the laws which govern the production or evolution of animal heat in health.

When the spinal cord of an animal is cut above the origin of the splanchnic nerves there is usually a great fall of the bodily temperature, which is in a measure proportionate to the temperature of the surrounding air. If the animal be placed in a heated apartment the fall of temperature is greatly lessened, and is sooner or later followed by a rise. In some animals the rise of temperature thus brought about is even greater than occurs in a normal animal placed in a similarly heated room. When the animal with a divided cord is in a cold room, death evidently is the result of the cold, the bodily temperature continually falling more and more until a point fatal to life is reached. The animal with a divided cord will live almost indefinitely in a room heated to 80°, but perishes in a very short time in a room of 40°. Another series of phenomena connected with spinal division is that where the cord is divided at its junction with the pons there is a very rapid rise of the bodily temperature, even in a cold room, to a point far above normal. It is plain that these phenomena may be either due to disturbances of heat evolution or of heat production, and that before any explanation of them can be satisfactorily given this point should be settled. This has been done by means of a calorimeter, whose general plan of construction resembles that of Senator. The principle of this is the heating of a given weight of water in a given time. This calorimeter measures only the amount of heat given off by the animal, or, in other words, heat evolution. If the animal gain in his bodily temperature during his stay in the calorimeter, it is plain that heat evolution is less than the heat production, and *vice versa.*

By taking the specific heat of the animal as the proportional mean of the specific heat of its constituents, namely as .75, we are able to calculate in heat units the amount of caloric lost or gained by the body, and to add to or subtract from the heat evolved as may be required to determine the amount of heat produced.

Employing this method it was found that immediately after section of the cord there is great increase of the heat evolution, if the calorimeter be at an ordinary temperature. On the other hand, when the hourly heat evolution was measured, some hours after the section, it was found to be much less than before the operation. The first increase of the heat evolution was always associated with a great fall of bodily temperature; and when the calculations were completed it was found that the extra heat imparted to the calorimeter during the first hour after the spinal section was not equal to the amount lost by the body, or, in other words, that immediately after the operation there was lessened heat production. In the subsequent hours of life, both heat production and evolution are markedly lessened. The result thus obtained may be stated as follows: Section of the cord at usual temperatures is followed by markedly lessened production of animal heat, continuing until death, and also by an immediate excessive loss of heat, which continues until the surplus caloric of the body has been yielded up, and then becomes proportionate to the diminished heat production.

The cause of the primary increased heat evolution is probably vasomotor palsy. The interior of the body maintains its temperature by keeping a partially cooled layer between it and the external air. When the external cold is great, the superficial vessels are contracted, and loss of heat is as far as possible prevented. After section of the cord, the superficial capillaries relax and the surface temperature rises. Later on, as the interior heat fails, the superficies and the deep parts of the body alike grow cooler, and the great loss of heat is arrested. A question now presented itself for solution, as to how far the loss of heat directly checks chemical movements inside of the body, and how far the lessened heat production after cord section is the direct result of such influence of the cold. This was partially solved by placing the animal in a calorimeter heated to about 100° Fahr. Under these circumstances it was found that sometimes the heat production was maintained after the operation, but in other cases was markedly diminished: the causes of the difference will be fully detailed in the extended memoir, but are here omitted. The calorimeter worked at a high temperature is not an instrument of precision, so that no absolute authority can be accorded to the experiments just spoken of. Nevertheless it will be seen that the results accord with the fact (earlier stated) that sometimes in the heated chamber rise of the bodily temperature was more pronounced after than before section of the cord. The evidence indicates that after spinal section the diminished heat production is not always or even usually in chief part caused by loss of heat, but that the reduction of temperature may have some influence in lessening the activity of the chemical movements of the body.

When the great rise of bodily temperature that follows immediately section of the cord above the governing vasomotor center in the medulla is called to mind, the necessity of studying as to whether this rise is due to disturbance of heat evolution or heat production becomes apparent. Such studies reached the result that heat production is excessively increased by section of the cord at its junction with the pons.

An elaborate series of experiments were performed confirming the results previously reached by other observers, that if changes in the arterial pressure can be taken as a guide, the governing vasomotor center is situated in the medulla oblongata. Conceding this, it would seem proven that vasomotor paralysis is the cause of the diminished heat production which usually follows section of the dorsal spinal cord, even when the bodily temperature is artificially maintained. It is plain how such palsy must everywhere render the circulation much less quick, more sluggish than normal, and this is probably the immediate cause of the failure of heat productions. The fact that sometimes, especially in very vigorous dogs, the production of heat was rather increased than lessened by spinal section, indicates that there is some influence at work antagonistic to the changes of the circulation, which is at times able to overcome the influence of these changes. This would seem to be rendered certain by the effects of section above the medulla, which was found to increase extraordinarily the production of the animal heat, the evolution not being notably affected. In one or more of the experiments the animal lived for twenty-four hours, and at the end of that time, notwithstanding no food had been ingested, the rate of heat production was still notably above normal. Where a result of nerve section remains for twenty-four hours it is usually considered paralytic, and it seems to me only the strongest arguments could establish that the increase of heat production just mentioned is of other character. Three theories suggest themselves as capable of accounting for the phenomena: first, that there is in the pons or higher up a center which inhibits chemical movements in the body, and that the section of the cord at the pons takes off from the general tissues this restraining influence; second, that the animal heat is mainly made in the muscle, and that the vasomotor center of the muscles is situated above the medulla, so that it is paralyzed when the section is made between the pons and medulla; third, that the section irritates the vasomotor centers and thus influences heat production by influencing the circulation.

The irritation theory was disproved by direct experiment, careful cardiometrical studies showing that the arterial pressure is not seriously affected by the operation, and that the circulation after the operation preserved all its normal relations with the organism below the section. Again, the persistence of the increased heat production for twenty-four hours seems very inconsistent with the irritation theory. Any one who has divided a spinal cord knows that all symptoms of irritation subside usually in a few minutes after a clean section. Finally, in two experiments punctures were made into the region of the junction of the medulla and pons, just sufficient to cause irritation, and the result was lessening of the heat production.

The conclusion that there is among the upper nerve-centers one which directly or indirectly controls the production of animal heat independently of the vasomotor centers of the medulla was further corroborated by a series of experiments of a different character from any as yet spoken of. If a sensitive nerve be galvanized there is a fall of the bodily temperature, which has usually been attributed to changes in the circulation and respiration. By experiments, which will be reported fully in the memoir, this fall of temperature is shown to be independent of the respiration, or of any changes in the blood pressure, such as is produced through the governing vasomotor centers of the medulla. Further, when the pons is separated from the medulla by section, it is impossible to produce a decided fall of the bodily temperature by galvanization of a sensitive nerve, although both circulation and respiration are apparently affected as in the normal animal. The only plausible explanation of this is that there is a nerve center above the point of section, which influences the development of animal heat independently of the respiratory or circulatory centers in the pons. It would seem, therefore, that we must adopt one of the first two theories as the true explanation of the phenomena observed. To decide which of the two is correct is not at present possible. We would naturally expect some distinct alteration of blood pressure to follow paralysis of the arterioles of the muscles, but the abdominal vessels are so enormous that it is possible that they are the dominating influence in the blood pressure. I am still engaged upon this subject, but what will come out of it is uncertain.

It having been noticed by Hitzig and other experimenters that wounds of certain portions of the brain cortex near the sulcus cruciatus are in the day followed by rise of temperature upon the opposite side of the body, attention was directed to this region. It was first proven by cardiometrical experiment that such wounds do not affect the general circulation to an appreciable extent. Seventeen calorimetrical experiments were there made. Five with destruction of both Hitzig's regions; result, average increase of heat production 53 per cent. Seven with destruction of one Hitzig region; result, average gain of heat production 19 per cent. Five with destruction of other portions of the cortex; result, in no case increase of the heat production. Then the same region was irritated with salt, and the heat production was found to be lessened. These results certainly are very extraordinary if there be no connection between this cortical region and the production of animal heat. Supposing the method of investigation faulty, the chances of nineteen successive experiments of different character, all concurring in their result, would be very small. When it is also borne in mind that these nineteen experiments are in accord with a long preceding series of complicated experiments, and that no exception has been met with, it is plain how small must be the chances of serious error either in the method or result.

In studying the subject of fever itself, the first question investigated was whether the febrile elevation of temperature be due to increased production, or simply lessened evolution of caloric. The experiments were mostly made upon dogs; each experiment lasted not less than three days, most of them six days; thermometrical readings being made every 20 minutes by night as by day. The normal and febrile states were studied, both when food was administered and when it was withheld. The first result was to show that there are two distinct varieties, so to speak, of animal heat, namely, that derived from the stored-up materials of the body, and that derived from the food; and that the second factor in the heat production is of great value, although it does not decidedly affect the bodily temperature. After a full meal, the amount of heat developed is enormous; but it is evolved as fast as produced. In fever little or no food is taken, and consequently this factor disappears. The heat produced at the expense of the stored materials of the body is always excessively increased in fever, and usually more than compensates for the loss of the food heat. In the dog at least, however, there are periods of high temperature in which less heat is being produced than after a full meal in the normal animal. It is plain that disturbance of the heat production is a factor of the febrile state; but it would seem that there is also a disturbance of the heat evolution, else more of the extra caloric would be gotten rid of. It has been shown that the diurnal rhythmic changes of temperature are usually parallel in health and fever; and it would seem that in regular fever there is a moving up of the habitual plane of heat upon which the organism is run. What has been made out as to the methods of heat production and evolution naturally suggests, as a plausible theory of fever, that the febrile state is chiefly due to a loss of power of the upper centers, musculo-vasomotor, or heat inhibiting, as the case may be, and to a less extent of sensibility of the vasomotor centers which preside over heat evolution. As the result of the weakening of the upper centers, more heat is developed; whilst the benumbed vasomotor centers require a greater degree of heat to stimulate them to throw off the excessive caloric produced. In investigating the truth of this theory, the first effort was to determine how fever is caused. Many fevers are evidently the result of the introduction of a poison in the blood; but it has been thought that inflammatory fever is produced by irritation of peripheral nerve. If, however, all the nerves going to the hind leg of a dog be divided, and after recovery has taken place the anæsthetic limb be wounded, traumatic fever is developed as soon and as intensely as in the normal animal similarly wounded. Such fever would seem to be due to an absorption of a poison into the blood; for fever is a general pathological process, involving the whole system, and the blood in the wounded animal, with divided nerves, is the one apparent channel of communication between the injured part and the general system. It is plain that a poison circulating in the blood may affect heat production, either by acting upon the nerve centers or by acting on the tissues of the body. There are certain clinical malarial phenomena which tell very strongly against the idea of fever being due to an action upon the universal protoplasm. Such phenomena are the regular sequence of complicated symptoms which usually make up the intermittent paroxysm; the frequent regular interchange between this fever paroxysm and neuralgic and other nerve storms, one replacing the other; the occasional occurrence of local paroxysms of intermittent fever involving only or chiefly certain regions of the body. To aid in elucidating the matter, two series of experiments were performed: In the first, the effect of section of the cord was studied in animals suffering from fever. The result was an exaggeration of the phenomena which occur after spinal section in the uninjured animal, heat evolution being enormously increased at first. This indicates that in fever the vasomotor nerves are more active in restraining heat evolution than in health. The second series of experiments consisted in irritating peripheral sensitive nerves in rabbits, upon successive non-fever days, and successive pyæmic febrile days. These experiments were made, and in each case, the same irritation being employed, the fall of temperature was much less upon the febrile than upon the non-febrile days. This, of course, indicates that in fever the inhibitory heat center is less powerful or active than in health.

In conclusion, the results reached in the research may be summed up as follows:

First. Fever is a morbid nutritive process, whose characteristic is excessive heat production.

Second. Heat evolution is under the control of the vasomotor nerve centers (the dominating center being situated in the floor of the fourth ventricle, near the point of the calamus); including also in man the nerves which preside over the secretion of sweat.

Third. Heat production is dominated by some higher nerve centers of uncertain nature.

Fourth. That in health there is in man, and probably in every animal, a fixed temperature mean, and a normal diurnal variation of temperature having a regular rhythm, which is beyond the control of all disturbing causes that do not force the organism beyond the limits of health.

Fifth. That the maintenance of the normal variation is the result of the play between the nervous systems which control the functions of heat production and evolution.

Sixth. Fever is a morbid process in which there is not only an elevation of the bodily temperature but also an increase in the chemical movements of the stored materials, *i. e.*, the tissues of the body; this increase being usually but not always much more than sufficient to compensate for the loss of food heat. The rise of the bodily temperature in fever is not solely dependent upon increased heat production.

Seventh. In fever there is usually a daily temperature variation parallel to and differing from the normal health variation only in having a higher mean.

Eighth. That vasomotor paralysis in fever is followed by an almost instantaneous sinking of temperature below normal, the fall being much more rapid and excessive than is produced by vasomotor paralysis in health.

Ninth. The higher centers which preside over the heat function are not paralyzed in pyæmic fever in the rabbit, but are certainly less capable than in health of responding promptly and powerfully to stimulation; or in other words they are in a condition of paresis.

Tenth. That the clinical phenomena of malarial and other fevers indicate that the febrile motion is of nervous origin.

Eleventh. That in most and probably in all continued fevers the symptoms are due to a poison in the blood.

Twelfth. That fever appears to be caused by a loss of functional activity in the higher centers which regulate the production and evolution of animal heat due to the action of a blood poison upon the centers.

UNIVERSITY OF PENNSYLVANIA,
Philadelphia, February 6, 1879.

CONSTANTS OF NATURE.

BY JOHN LE CONTE,

Of the University of California.

[*Vide.* Paper on "Sound" in "Lond., Edin., Dub., Phil., Mag." 4th Series, Vol. 27, pp. 15, 16, 17, 18, 29 *et seq.*—January, 1864.]

	Constants.	Logarithms.
Weight of 1 litre of mercury at Paris, 60 metres above sea, at 0° C	13595.93 grammes	4. 13340,89199
Weight of 1 cubic foot (English) of same	848.7196416 pounds avoirdupois	2. 92876,42591
Weight of 1 cubic inch (English) of same	0.4911572 pounds avoirdupois	−1. 69122,05210
Do	3438.1004 grains	3. 53631,85610
Weight of 1 litre of pure, dry air at Paris, 60 metres above sea, at 0° C., pressure $=760$ mm of mercury, at 0° C	1.2932227 grammes	0. 11167,33192
Weight of same at sea-level	1.2932388 grammes	0. 11167,87259
Weight of same at equator	1.2893600 grammes	0. 11037,41927
Weight of same at latitude 45°	1.2927818 grammes	0. 11152,52294
Weight of same with 0.0004 volumes of CO_2 at Paris, height $=60^m$	1.2934963 grammes	0. 11176,51908
Do., at Paris, height $=0^m$	1.2935124 grammes	0. 11177,05964
Do., at equator, height $=0^m$	1.2896328 grammes	0. 11046,60703
Do., at latitude 45°, height$=0^m$	1.2930553 grammes	0. 11161,70987
Weight of 1 cubic foot (English) of pure, dry air at Paris, height $=60^m$, at 0° C., pressure $=760$ mm of mercury	0.0807288 pounds avoirdupois	−2. 90702,86584
Weight of 1 cubic foot of same	565.101792 grains	2. 75212,66984
Weight of 1 cubic inch of same	0.3270265 grains	−1. 51458,29603
Weight of 1 cubic foot with CO_2	0.0807459 pounds avoirdupois	−2. 90712,05300
Do	565.22137 grains	2. 75221,85700
Weight of 1 cubic inch with CO_2	0.3270957 grains	−1. 51467,48319

$$\text{Weight of 1 litre of air}=\frac{1.2893600}{1+0.00367\times t}\times\frac{b-0.378\times f}{760}\times\left(1-\frac{1.32\times h}{r}\right)\times\left(1+0.005307746\times\sin^2\text{lat.}\right)$$

$$\text{Weight of 1 litre of air}+CO_2=\frac{1.2896328}{1+0.00367\times t}\times\frac{b-0.378\times f}{760}\times\left(1-\frac{1.32\times h}{r}\right)\times\left(1+0.005307746\times\sin^2\text{lat.}\right)$$

[Weight in grammes: $t=C°$; $b=$ height of bar in mm of merc. at 0° C: $f=$ tension of aq. vap. in mm of merc. at 0° C: $h=$ height above sea-level: $r=$ rad. of earth.]

$\frac{\text{Dens. merc.}}{\text{Dens. air}}$: $t=0°$ C : pr. $=0^m.76$	At Paris, height $=60^m=10{,}513.2163$	4. 02173,56007
Do	At Paris, height $=0^m=10{,}513.085$	4. 02173,01940
Do	At equator, height $=0^m=10{,}544.712$	4. 02303,47272
Do	At latitude 45°, height $=0^m=10{,}516.802$	4. 02188,36905
Same $+CO_2$	At Paris, height $=60^m=10{,}510.992$	4. 02164,37291
Do	At Paris, height $=0^m=10{,}510.861$	4. 02163,83235
Do	At equator, height $=0^m=10{,}542.481$	4. 02294,28496
Do	At latitude 45°, height $=0^m=10{,}514.577$	4. 02179,18212
Pressure of atmosphere at $t=0°$ C : bar $=0^m.76$ of mercury	On square centim. $=1033.29068$ grammes	3. 01422,25122
Do	On square centim. $=1.03329068$ kilogrammes	0. 01422,25122
Do	On square metre $=10332.9068$ kilogrammes	4. 01422.25122
Do	On square inch $=14.6963$ pounds avoirdupois	1. 16720,82426
Do	On square foot $=2116.268$ pounds avoirdupois	3. 32557,07347
Height of homogeneous atmosphere of air, at $t=0°$ C	$=7990.044388$ metres	3. 90254,91930
Do	$=26214.52864$ (English) feet	4. 41854,20762

	Constants.	Logarithms.
Length of seconds' Pend. Biot's results corrected....	At Paris, height = 60^{m} = 0^{m}.99390,2053....	—1. 99734,35877
Do....	At Paris, height = 0^{m} = 0^{m}.99391,4420....	—1. 99734,89915
Do....	At equator, height = 0^{m} = 0^{m}.99093,3412....	—1. 99604,44721
Do....	At latitude 45°, height = 0^{m} = 0^{m}.99356,3224....	—1. 99719.55080
Do....	At pole, height = 0^{m} = 0^{m}.99619,3035....	—1. 99834,35010
Do....	At London, height = 0^{m} = 0^{m}.99418,3474....	—1. 99746,65397
Do....	At London, height = 0^{m} = 3^{ft}.26181.573.....	0. 51345,94229
Do....	At London, height = 0^{m} = 39^{in}.14178,878.....	1. 59264,06690

The value for London has been computed from Sabine's experiments. (Phil. Trans. for 1828), corrected by Baily (Mem. of Ast. Society, vol. 7).

$$\text{L in metres} = 0^{m}.990933412\left(1-\frac{1.32\times h}{r}\right)\times\left(1+0.005307746\times\sin^{2}\text{lat.}\right)$$

Velocity generated by gravity (g) in a mean solar second of time...	At Paris, height = 60^{m} = 9^{m}.80942,005.....	0. 99164,33331
Do....	At Paris, height = 0^{m} = 9^{m}.80954,210	0. 99164,87369
Do....	At latitude 0°, height = 0^{m} = 9^{m}.78012,073.....	0. 99034,42175
Do....	At latitude 45°, height = 0^{m} = 9^{m}.80607,593.....	0. 99149,52534
Do....	At latitude 90°, height = 0^{m} = 9^{m}.83203,113.....	0. 99264,32454
Do....	At London, height = 0^{m} = 9^{m}.81219,755.....	0. 99176,62851
Do....	At London, height = 0^{m} = 32^{ft}.19283,06......	1. 50775,91683

$$g\text{ in metres} = 9^{m}.78012073\left(1-\frac{1.32\times h}{r}\right)\times\left(1+0.005307746\times\sin^{2}\text{lat.}\right)$$

Theoretical velocity of sound (Newton's formula) in dry air, at t = 0° C	279.9602 metres per second	2. 44709,62631
Do....	918.5210 feet per second	2. 96308,91463
Experimental velocity of sound in dry air, at t = 0° C: Dutch experiments corrected, by Le Conte.	332.7167 metres per second	2. 52207.47
Do....	1091.610 feet per second	3. 03806,76
By Van der Kolk	332.6724 metres per second	2. 52201,67
Do....	1091.464 feet per second	3. 03800,96
Density of gas; air = 1. Regnault's results *corrected:*		
Oxygen	1.105612	0. 04360,27
Nitrogen....	0.971346	—1. 98737,39
Hydrogen....	0.069269	—2. 84053,89
CO_2	1.529100	0. 18443,59

LIST OF APPARATUS RELATING TO HEAT, LIGHT, ELECTRICITY, MAGNETISM, AND SOUND, AVAILABLE FOR SCIENTIFIC RESEARCHES INVOLVING ACCURATE MEASUREMENTS.*

Professors WOLCOTT GIBBS, EDWARD C. PICKERING, and JOHN TROWBRIDGE, of Harvard University, have lately corresponded with the leading institutions of learning, and obtained consent for the use of the below-mentioned instruments for purposes of research by properly-qualified persons.

UNITED STATES COAST AND GEODETIC SURVEY OFFICE, WASHINGTON, D. C.

The use of this apparatus may be had at the office, under appropriate regulations. Applications must be made to Capt. C. P. PATTERSON, Superintendent United States Coast Survey.

1. *Comparators of length:*

a. Saxton's pyrometer, or mirror comparator, for end measures.

b. Repsold's contact-lever comparator, for end measures.

c. Saxton's tracing and comparing machine, for line measures.

d. Hilgard's comparator, for line and end measures for any length between three and forty inches.

e. Rutherfurd's micrometer, with two screws at right angles, and circle of position for measuring stellar and solar photographs.

2. *Standards of length:*

a. Standard iron meter of original committee for establishing metric system (end measure).

b. Standard British yard (line measure).

Standard British yard (end measure).

Eighty-four-inch scale, divided to tenths of inches, made by Troughton and compared throughout by Hassler.

c. Decimetre divided into centimetres and millimetres, compared with the original standard metre.

d. Copy of toise, accurately compared.

3. *Apparatus for weighing.*—Balances of precision for maximum charges of 100, 10, and 1 kilogrammes, and 100 and 1 grammes.

4. *Standard weights.*—Standard troy and avoirdupois pounds; kilogramme in platinum and in brass accurately compared.

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*From the Scientific American Supplement for August, 1879.

American Academy of Arts and Sciences, Boston, Mass.

Applications for use must be made to Prof. Joseph Lovering, chairman of the Rumford Committee, Cambridge, Mass.

1. *Meyerstein's spectrometer.*—Aperture of collimator and telescope, 3.3 centimetres; magnifying power of telescope 18 times; graduated circle reads by means of two micrometers to two seconds. Instrument intended to be used with a diagonal eye-piece for obtaining reflection at right angles to the reflecting surface. It is not well adapted for measuring indices of refraction, except by the special method for which the instrument was designed.

2. *Large hollow prism* of glass, with movable glass faces, held in their places by springs. Angle 60°.

3. *Prof. J. Trowbridge's electro-dynamometer.*—Instrument for measuring the strength of powerful electric currents such as are produced by dynamo-electric machines. Mean radius of fixed coils 153.3 millimetres. Instrument described in Proceedings of American Academy of Arts and Sciences, October 9, 1878.

4. Thomson's galvanometer, resistance 6 ohms.

5. *Micrometer-level*, constructed by Alvan Clark & Sons. Telescope, 45 centimetres focal length and 4 centimetres aperture, in Y's moved by vertical micrometer screw, reading to 0.3″ by estimation of tenths. Intended also for use with eye-piece micrometer. One division of level tube (0.15 cm.) = 8.7″. Transverse level and slow motion for rotating telescope in Y's. Horizontal finding circle graduated to degrees.

6. *Light micrometer-level.*—Telescope 21 centimetres focal length and 25 centimetres aperture, in Y's moved by vertical micrometer screw, reading to 1.4″ by estimation of tenths. One division of level tube (0.25 cm.) = 1.8″. Horizontal finding circle graduated to degrees.

7. *Microscope-tube* and accessories, specially designed for measuring spectrum photographs. Also a *standard plate* of 24ths of an inch; rulings on glass by Prof. William A. Rogers.

8. *A large double induction coil* of the form devised by Prof. John Trowbridge.

9. *Apparatus for the determination of the mechanical equivalent of heat.*—Devised by Prof. Henry A. Rowland, of Johns Hopkins University, and now in his charge.

Harvard University.—Rumford Cabinet, Cambridge, Mass.

(In charge of Professor Wolcott Gibbs.)

1. *A spectrometer* by Brunner Frères, of Paris. The instrument has a single-graduated circle 10 centimetres radius, reading by two verniers to 5 seconds of arc, and by a micrometer eye-piece to about 2 seconds. The telescope and collimator have 33 centimetres focal length, and 3.4 centimetres aperture. The micrometer is provided with cross and also

with parallel spider lines, and with a separate collimating eye-piece. The spectrometer stands upon a plate of metal which can be made to revolve, so that measurements by repetition are practicable. The instrument is in perfect adjustment, and has everything necessary for the determination of wave lengths and of indices of refraction. In connection with it the Rumford cabinet possesses:

2. Two gratings, Nos. 1 and 2, ruled on speculum metal by D. C. Chapman with Mr. Rutherfurd's engine. One of these, No. 1, has 8,648 lines to the inch and a ruled surface (4.3 cm. × 5.2 cm.). The other has 17,296 lines to the inch and the same ruled surface as No. 1. They may be adjusted to the spectrometer above described by plate-holders constructed by William Grunow, of New York, with all necessary requirements for the measurement of wave lengths.

3. A collimator, 1.6 metres focal length and 6.5 centimetres aperture, mounted upon a stand and specially adapted to the study of the extreme visible red and violet ends of the spectrum. Object-glass by Alvan Clark & Sons. A quartz lens of same focal length is to be added to this instrument from the workshop of Steeg & Reuter, in Homburg vor der Höhe, as well as a telescope with quartz objective and eye-piece for observing the ultra-violet spectrum.

4. *A porte-lumière*, by Duboscq. A Foucault's heliostat has been ordered, and may be expected in the course of the summer.

5. *Vierordt's apparatus* for measuring the intensity of light corresponding to any part of the visible spectrum. Telescope and collimator 25 centimetres focal length. Apertures, 2.8 centimetres and 2.1 centimetres. The instrument was made by Schmidt & Haensch, of Berlin, and is complete with prism and colored glasses.

6. *A direct-vision spectroscope*, with two sets of 9 prisms each. Set 1 contains 4 prisms of carbonic disulphide and 5 of crown glass. Set 2 consists of 4 prisms of flint and 5 of crown. The length of the instrument is 60 centimetres. It is provided with a scale telescope, and the observing telescope has the usual angular motion. This instrument is also by Schmidt & Haensch.

7. *An inductorium*, by Apps, of London, giving a 4-inch spark.

8. *Three thermometers*, by Baudin, of Paris, reading to .01 degree centigrade.

No. 1. Reading from 0.° to 12° centigrade.

No. 2. Reading from 12° to 23°.

No. 3. Reading from 23° to 35°.

In these instruments the weights of the bulbs, stems, and contained mercury are given.

9. *Edison's tasimeter*, made by Patrick & Carter, of Philadelphia, and adjusted by Mr. Edison. See *American Journal of Arts and Sciences*, 3d series, Vol. XVII, p. 52. A galvanometer suited to this instrument will be found in the cabinet in charge of Professor Trowbridge, together with the requisite batteries and Wheatstone's bridge.

In connection with these instruments the following, belonging to the Rumford professor, are also available:

1. *A large spectroscope* with telescope and collimator of 4.75 centimetres aperture and 5.5 centimetres focal length. Magnifying power from 8 to 60 times. Object-glasses by Fitz, of New York. Six hollow prisms of carbonic disulphide—glass faces 6×8 centimetres—arranged on Mr. Rutherfurd's plan, so that all the prisms are constantly in the position of minimum deviation. The stand, observing telescope, and prisms of this instrument may be used in connection with the long collimator belonging to the Rumford cabinet.

2. *A large hollow prism*, with angle of 30°—glass faces 6×8.5 centimetres—for Professor Gibbs's solution of phosphorus and sulphur in carbonic disulphide. See *American Journal of Science and Arts*, Vol. IV, p. 6, 2d series.

3. *Two flint-glass prisms*—faces 8.5×5 centimetres—which may be used singly or together. Angles of 60°.

4. *Professor Gibbs's double or compensating prism* for the study of absorption spectra. See *American Journal of Arts and Sciences*, Vol. IV, p. 8.

5. *Five gratings* ruled with Mr. Rutherfurd's engine:

No. 1. Ruled on speculum metal, 6,480 lines to the inch. Ruled surface 2.1×2.8 centimetres. Metal a little tarnished.

No. 2. Ruled on glass and silvered, 8,640 lines to the inch; 7,021 lines upon a ruled surface 2×2.7 centimetres. Covering-plate of glass cemented with Canada balsam.

No. 3. Ruled on glass for spectra by transmission, 6,480 lines to the inch. Ruled surface 1.7×2.7 centimetres.

No. 4. Ruled on glass for transmission of light, 12,960 lines to the inch. Ruled surface 1.3×2.7 centimetres.

No. 5. Ruled on glass and silvered; 13,321 lines on a space 19×24 centimetres, with covering-glass cemented by Canada balsam.

Kirchhoff's, Angström's, and Mascart's maps of the spectrum.

Mr. Rutherfurd's original photographs, together with the German lithographic reproduction of the same.

Mr. Rutherfurd's recent photographs taken with the diffraction spectrum. Thalen's map of the absorptive bands of iodine vapor.

The thermometers by Fastré, of Paris, carefully compared with an air thermometer reading from 0° to 100° C.

HARVARD UNIVERSITY.—DEPARTMENT OF PHYSICS.

(In charge of Professor JOHN TROWBRIDGE.)

1. *Edelmann's* instrument for measuring horizontal and vertical intensity of earth's magnetism.

The peculiarity of this instrument consists in its allowance of a long suspension, and in its torsion head.

2. *A standard ohm*, and two boxes of resistance coils running from one to five thousand ohms.

3. *An induction coil* made in the horseshoe form and provided with iron plates for armatures. The two induction coils comprise a resistance of 12,000 ohms.

4. *Galvanometer for absolute measure.*—Maker: Edelmann, Munich. A short coil minor instrument, adapted for absolute measures by certain methods. Resistance, 6 ohms.

5. *Thomson's reflecting galvanometers.*—One of 5,880 ohms resistance—a differential instrument.

One of 6 ohms resistance, adapted for heat measures.

6. *Thomson's quadrant electrometer.*—Made by White, of Glasgow.

7. *Cathetometer.*—Maker: Perreaux, Paris. Reads by vernier to 2-100ths of millimetre, or by micrometer to 1-100th of a millimetre. Focal length of objective, 13 centimetres; magnifying power of telescope 30 times.

8. *Dividing engine.*—Maker: Perreaux, Paris. Screw, 61 centimetres long. Pitch of screw, one-half of a millimetre. Micrometer reads to one four-hundredth of a millimetre. Instrument adapted only for graduating tubes and scales, or for comparison of graduations.

9. *Large spectroscope.*—Designed by Professor J. P. Cooke, of Harvard University. Two trains of prisms. One of nine bisulphide of carbon prisms of 45°. One of nine flint-glass prisms of 45°. Graduated circle reading to 10 seconds, also a micrometer eye-piece. Magnifying power of telescope, 10 times; focal length of objective, 46 centimetres; aperture, 5.5 centimetres.

10. *Reading telescope and scale.*—On brass leveling stand. Telescope provided with two objectives: one for short, the other for long, distances.

Magnifying power for long distances, 22 times.

Magnifying power for short distances, 30 times.

Focal length of the objective for long distances, 30 centimetres.

Focal length of the objective for short distances, 23 centimetres.

Aperture of objectives, four centimetres.

HARVARD UNIVERSITY.—ASTRONOMICAL OBSERVATORY.

(In charge of Professor E. C. PICKERING.)

LIST OF INSTRUMENTS NOT IN CONSTANT USE AND AVAILABLE FOR RESEARCH.

1. *East transit circle*, by Troughton and Simms, of London. Aperture of telescope, 4¼ inches; focal length, 5 feet. Described in Vol. I, pt. 1, of the Annals of the Observatory, p. 46.

2. *West equatorial*, by Alvan Clark & Sons, of Cambridge. Aperture of telescope, 5¼ inches; focal length, 7½ feet. Described in Vol. VIII of the Annals of the Observatory, p. 31.

3. *Portable transit instrument*, by Herbst, of Pulkowa. Aperture of telescope, 2¾ inches; focal length, 33 inches. Eye-piece at end of axis. Described in Vol. VIII of the Annals of the Observatory, p. 28.

4. *Bowditch comet-seeker.*—Aperture, 4 inches; focal length, 33 inches. Described in Vol. VIII of the Annals of the Observatory, p. 32.

5. *Telescope*, by Lerebours. Aperture, 3 inches; focal length, 50 inches.

6. *Telescope*, by Alvan Clark & Sons. Aperture, 3⅛ inches; focal length, 39 inches. Object-glass slightly damaged.

7. *Variation transit*, by Troughton & Simms, of London. Aperture of telescope, 1¾ inches; focal length, 18 inches.

8. *Traveler's transit theodolite*, No. 3527, by L. P. Casella.

9. *Sextant*, by Spencer, Browning & Rust.

10. *Spectroscope*, by Troughton & Simms, of London, with two prisms, and Professor Winlock's apparatus for recording observations, as described in Vol. VIII of the Annals of the Observatory, p. 33.

11. *Spectroscope*, by J. Browning, of London, with one prism, and Professor Winlock's apparatus for recording observations.

12. *Spectroscope*, by Alvan Clark & Sons, of Cambridge, with five prisms and reflecting prism to send the light a second time through them. Dispersive power exceeding that of 22 ordinary prisms. Prisms not movable. Described in Vol. VIII of the Annals of the Observatory, p. 35.

13. *Lens of plate glass.*—Focal length, about 40 feet; aperture, 4 inches.

14. *Lens corrected for chemical rays.*—Focal length, 32 feet 5 inches; aperture, 4 inches.

15. *Photometer*, by Ausfeld, of Gotha, on plan of Professor Zöllner.

16. *Occultator* (for computation of occultations), on plan of Rev. Thomas Hill.

17. *Position circle*, read by verniers to minutes of arc.

18. *Thermometric chronometer*, by C. Frodsham, of London, No. 3,424, constructed so as to increase its daily rate by 6.11″ on a reduction of one degree Fahrenheit.

19. *Clock*, by W. Bond & Son, of Boston, No. 312.

20. *Small chronograph*, by Herbst, of Pulkowa.

21. *Portions of the magnetic apparatus* described in Vol. I, part 1, of the Annals of the Observatory.

(Property of Professor WILLIAM A. ROGERS.)

1. Small line and circle graduating engine. This machine is designed for all kinds of graduations, in which the length of the line to be ruled does not exceed 2 inches. The errors of the screw for one-thousandth of an inch have been carefully investigated. It is not automatic in its action, and hence it is not adapted to ruling diffraction gratings. The circular graduations are only approximate.

2. Machine for original graduation of circles from 1-inch to 15-inch disk.

3. Machine for shaping and polishing diamonds for marking on glass and on all kinds of metals.

4. Microscope comparator for short lengths.

5. Comparator for long standards of length.

6. In process of construction at the Waltham Watch Factory: A universal line graduation engine. This machine is designed:

(1). To rule Nobert's bands.

(2). To graduate both short and long standards of length.

(3). To rule diffraction gratings in which—

(*a*) Any required relation between the relative width of the lines and the spaces may be secured.

(*b*) Errors of any required magnitude may be introduced, whether individual or systematic, without interference with the remaining graduations.

HARVARD UNIVERSITY.—MEDICAL SCHOOL PHYSIOLOGICAL LABORATORY.

(In charge of Prof. H. P. BOWDITCH.)

1. *Thomson's galvanometer*, No. 26, Elliott Brothers. Resistance at 55° F. = 5,995 B. A. units.

2. *Wiedemann's galvanometer*, with mirror and two pairs of coils of 4,000 and 98 turns respectively.

3. *British Association unit of resistance*, No. 74, right at 15.5° C.

4. *Pendulum myograph*, described by Dr. J. J. Putnam at the American Academy, March, 1879.

5. *Cylinder chronograph:* Baltzar, Karolinen Strasse, 14, Leipsic.

6. *Chronograph*, with long roll of paper. Baltzar. Leipsic.

7. *Clock* for making or breaking an electrical circuit once in 1, 2, 3, 4, 5, 10, 15, 20, 30, or 60 seconds, the duration of the make or break variable from 0 to 4 seconds.

STEVENS INSTITUTE OF TECHNOLOGY, HOBOKEN, N. J.

(For the use of this apparatus application may be made to Prof. A. M. MAYER.)

1. *Apparatus for the determination of coefficients of expansion.*—Consists of the tube (invented by Professor Mayer) to hold the rod under measurement. This tube is so constructed that the rod up to its terminal planes is kept permanently at the temperature of melting ice, or at the boiling-point, or at any intermediate temperature, by passing a current of water or hot oil through the tube; at the same time the terminal planes of the rod are exposed for abutment against micrometer screws, &c. The rod is supported in the tube at quarters of its length from its

ends, and the weight of tube and inclosed rod is taken off the V's of the apparatus by straps and spring balances.

The measuring part of the apparatus is entirely distinct, and at a distance from the tube. The tube is only placed in contact with the measuring apparatus *at the moment* of making the measurement.

The measures are made by Saxton's reflecting comparator, or by micrometer screws brought up to the ends of the rod, and contact determined by the closing of a voltaic circuit.

Successive contacts, made by successively placing the rod (cooled to melting ice), give a range of measures on a rod one metre long, equal to about 1-30,000th of an inch. Micrometer screws, pitch 1-50th and 1-100th inch.

2. *Vertical comparator*, with contact lever, micrometer screw, pitch = 1-100th inch. Well made, heavy cast-iron frame of T section, mounted on a cast-iron tripod base.

3. *Apparatus for the comparison of yard and metre* (end or line measures) by Airy's method. Massive cast-iron plate with guides, two micrometer microscopes, with apparatus for handling measures.

4. *Spectrometer.*—Circle divided by Brunner of Paris, reading by vernier to 5″. Telescopes: one set, one inch aperture, 10-inch focus. Another set: collimator, 5 feet long, and observing telescope, 18 inches focus. (*Property of Professor Mayer.*)

5. *Interferential refractometer of Arago.*—Tube of one metre for holding gas whose index of refraction is to be measured. Collimator, six inches; observing telescope, three-quarters of a metre focus.

6. *Two of Hipp's chronoscopes.*

7. *Electric clock*, to be used in connection with inductorium and rotating cylinder, to determine the number of vibrations of tuning-forks and other solid bodies.

8. *Spherometer*, by Brunner, of Paris, furnished with a contact lever. Pitch of screw 0.5 millimeter.

9. *Full sets of resistance coils*, condensers, and high and low resistance Thomson galvanometers.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.—DEPARTMENT OF PHYSICS, BOSTON, MASS.

(In charge of Professor CHARLES R. CROSS.)

1. *Cathetometer*, by Staudinger. Scale graduated to millimetres; length, 1,020 millimetres. Vernier reads directly to 1-20th millimetre. Focal length of telescope is 280 millimetres. One division of level corresponds to 5″.

2. *Dividing engine*, by Buff and Berger. The microscope is carried by two screws moving at right angles to each other, so as to give two coordinates. The pitch is 1-20th inch, and the length of the screws, 16 inches and 4.5 inches respectively. Circles are divided into 100 parts,

read by estimation to tenths. The instrument is arranged especially for measurement rather than for graduation.

3. *Spectrometer*, by Clark. Furnished with five 60° and one 30° prisms, the latter silvered on its rear surface. A greater or less number of prisms can be used at will. Face of prisms 5.7 centimetres by 7.3 centimetres. Focal length of telescope, 70 centimetres; diameter of object-glass 5.2 centimetres. Diameter of circle, 43.5 centimetres, reading to 10″ by verniers. Smaller angles are measured by spider-line micrometer. The same telescope serves as collimator and observing telescope, the method of reflection from the silvered surface of the glass being used.

4. *Diffraction grating*, ruled by Chapman on Mr. Rutherfurd's engine. 17,256 lines to an inch; 30,600 spaces. Area of ruling, 4.5 centimetres square.

2. *Two prisms of quartz*, 60°, faces 5.5 centimetres by 4.0 centimetres. Also various prisms of flint glass and heavy glass.

Eaton's direct-vision prism of glass and carbon disulphide. Small direct-vision prisms of glass.

6. *Polarimeter* of Professor Pickering, for sky-polarization. See *Proc. Am. Acad.*, Vol. IX.

7. *Wheatstone's bridge*, by Elliott, measuring from .001 to 1,000,000 ohms.

8. *Thomson's long-coil galvanometer.*—Resistance, 3,000 ohms. Thomson's short-coil galvanometer for thermo-electrical work; resistance, 6-10 ohm.

9. *B. A. divided metre bridge.*

10. *Tangent galvanometer.*—36 coils, 26 centimetres radius. Gaugain tangent and sine galvanometer. Cosine galvanometer.

11. *Induction coil*, by Ritchie, giving 6-inch spark.

Columbia College, New York.

(In charge of Professor O. N. Rood.)

1. *Newman's standard barometer;* diameter of tube, 0.6 inch; reads to 1-500 inch.

2. *Grunow's spectrometer.*—Focal length of lenses, 14 inches; diameter of circle, 9 inches; aperture, 1.3 inches; reads to 10 seconds.

3. *Cathetometer.*—Length, 800^{mm}; focal length of telescope, 10 inches; aperture, 1.1 inches. Provided with extra object-glass for reading at short distances.

4. *Wild's photometer*, simple construction, diameter of circle, 6 inches.

5. *Apparatus* for measuring the velocity of sound in rods of wood by means of longitudinal vibrations. Described in *American Journal of Science*, Vol. XVII.

6. *Magneto-electric machine*, by Wallace (no motor).

7. *Ruhmkorff's diamagnetic apparatus.*

8. *Tangent compass.*—Diameter of circle, 13.5 inches.
9. *Original Siemens' unit.*
10. *Helmholtz apparatus for vocal sounds.*
11. *Koenig's phonautograph.*
12. *Koenig's cylinder* for determining the vibrations of tuning-forks.
13. *Nachet's large inverted microscope.*
14. *Koenig's monochord.*
15. *Lissajou's comparator.*
16. *Comparator* for the standard yard.

JOHNS HOPKINS UNIVERSITY.—PHYSICAL LABORATORY, BALTIMORE, MD.

(In charge of Professor HENRY A. ROWLAND.)

The list does not include apparatus for demonstration.

ACOUSTICS.

All the ordinary apparatus by Koenig, of Paris, including Helmholtz's double sirens, Lissajou's vibrating microscope, Hastings's pendulum comparator, &c.

OPTICS.

Meyerstein spectrometer—large model. The circle is of 16 centimetres radius, divided on silver to 6′ and reading by two microscopes to 2″. The probable and periodic errors of graduation have been investigated, and are given in the *American Journal of Science*, Vol. XV., p. 270. Having a common axis with the large circle is a table rotating independently, 6.5 centimetres radius, graduated on silver limb and by two verniers to single minutes. The massive stand has a joint by which the circle may be brought into a vertical plane. Aperture of telescope and collimator, 4.0 centimeters; focal length, 34 centimetres; powers, from 13 upward. A smaller telescope, 2.0 centimetres aperture, 18.0 centimetres focal length, power 7, may be placed on a third support rigidly connected with the microscope bearers. The accessories of this instrument are:

(*a.*) Two telescopes with Nicol prisms before objectives; longer diagonals of prisms, 2.0 centimetres; length of telescopes, 20.0 centimetres; power 3; position-angles of prisms read by circles of 3.5 centimeters radius to minutes of arc.

(*b.*) Babinet's compensator with wedge of 3 centimetres available length.

(*c.*) High power collimating ocular.

(*d.*) Low power collimating ocular.

(*e.*) Three micrometer eye-pieces.

2. *Spectrometer*, by Schmidt and Haensch. The circle has a silver limb 16 centimetres radius, divided to 6′ and read by microscopes to 2″.

Table in center has a graduation 6.0 centimetres radius, reading by verniers to 1′. Aperture of objectives of telescope and collimator, 3.9 centimetres; focal length, 35.0 centimetres; power, 13. The angle between lines of collimation of telescope and collimator may be read by small circle to single degrees.

3. *Steinheil's spectroscope.*—The clear aperture of train, including two 60° prisms, is 4.0 centimetres. Focal length of collimator and telescope, 32.5 centimetres; powers, 8, 12, &c. Photographic scale.

4. *Silbermann's heliostat, &c.*—This instrument, by Duboscq, has two mirrors 18.0 centimetres by 9.0 centimetres, one silver under glass and the other silver. Also, *porte-lumière.*

5. *Jamin's interferential refractometer*, with tubes 100 centimetres long, for the study of refraction in gases, and a glass trough 20 centimetres long for liquids, by Duboscq.

6. Complete apparatus for the study of phenomena of interference, by Duboscq.

7. *Photographic apparatus.*—Objective 6.1 centimetres aperture, and about 40 centimetres focal length for plates; 10×12 inches, by Steinheil. Dark room, collection of chemicals, and everything necessary for experiments on the subject.

8. *Becquerel's phosphoroscope*, by Duboscq.

9. *Polarizing apparatus*, from Steeg; also from Duboscq.

10. Apparatus for producing monochromatic light of any color. Designed by Hastings and made by Schneider.

11. *Prisms, gratings, &c.*

a. Hollow prism from Meyerstein; aperture, 6.1×5.2 centimetres.

b. Hollow prism from Steinheil; aperture, 2.2 centimetres.

c. Thallium glass prism from Steinheil; aperture, 4.8 centimetres.

d. Two flint glass prisms from Steinheil; aperture, 4.7 centimetres.

e. Crown glass prisms from Steinheil; aperture, 4.8 centimetres.

f. Two quartz prisms from Steeg; faces, 3.4×3.0 centimetres.

g. Iceland spar prism; faces, 2.6×2.2 centimetres, by Steeg.

h. Two rock-salt prisms, faces, 5.0×4.0 centimetres, by Steeg. Also rock-salt lens.

i. Large Nicol's prism, largest diagonal 6.5 centimetres. Also a number of smaller ones.

j. Gratings on speculum metal, 4.3×3.9 centimetres, with 8,648 lines to the inch, and 4.4×4.4 centimetres, with 17,396 lines to the inch, and a smaller glass grating, with 8,648 lines to the inch, all by Chapman with Rutherfurd's engine.

Kirchoff's, Angström's, and Rutherfurd's maps of the solar spectrum.

k. Old telescope by Dollond. Objective about 4 inches diameter and 6 feet focal length.

ELECTRICITY AND MAGNETISM.

The distinguishing feature of the apparatus for these subjects is its accuracy and the determination of the constants in absolute measure.

12. *Rowland's absolute electrometer* for potentials represented by sparks of about 0.1 to 1 inch. Designed on Sir William Thomson's guard-ring principle, and constructed by Edelmann, of Munich. Guard-ring, 33.5 centimetres, and can be separated about 7 centimetres, the distance being read by vernier to 0.01 centimetre. Movable disk, 10 centimetres diameter, and *firmly* attached to arm of a balance sensitive to 1 mgr. Balance moves only 0.01 centimetre, and means of two distances of the disks are taken, the one to move it to upper and the other to lower stop. Weights of from 1 to 5 grammes ordinarily used. *Disks ground and polished to mirror surface after nickel-plating.*

13. *Rowland's electrostatic standard condenser.*—Constructed by Grunow, of New York. One sphere within the other *nickel-plated and ground to mirror surface,* with extra ball for interior. Balls, 7 and 8 inches diameter. Hollow sphere, 10 inches diameter. Apparatus for centering. Radii determined by loss of weight in water. Can be charged and discharged any number of times at rate of three per second, by means of fine wires which pass in momentarily from outside, and so do not change the capacity much. Any condenser can be compared with it by means of an electrometer.

14. *Thomson's quadrant electrometer,* by White, of Glasgow, with Thomson's key.

15. *Condenser,* 1-3 microfarad, by Elliott.

16. *Commutators* for high (say 1 inch spark) as well as low tension.

17. *Rowland's galvanometer* for the absolute measurement of discharges of high tension. Constructed by Rowland & Schneider. Coils wound with paper between, and boiled in paraffine *in vacuo* at 100° C., to be thoroughly dry. Needle shielded from electrostatic action, and deflection read by mirror and scale. Number of coils about 11,000. Constant on the cm. gr. second system 19091.=G of Maxwell, as determined by comparison with galvanometer described in *American Journal of Science,* Vol. XV, p. 334. See No. 27, below.

18. *Rowland's absolute galvanometer* for the measure of quick, weak currents. Constant, 1833.2. See *American Journal of Science,* Vol. XV, p. 334. Constant very accurately known. 1,790 turns. Can be used as sine galvanometer or with mirror and scale. Horizontal circle reads to 1′, but is readily estimated to 30″. Telescope and bar for determining horizontal intensity in exact position of instrument.

19. *Rowland's tangent galvanometer,* brass circle, 50 centimetres diameter. Circle graduated to 15′ and 20 centimetres diameter. From 1 to 243 turns can be used, the constant of each set being known with great accuracy. Made by Meyerstein, but altered and wound and coils measured by Rowland.

20. *Two Thomson's galvanometers* of high and low resistance, the first differential with coils around both needles and set of shunts. Made by Elliott, of London.

21. *Two Nobili astatic galvanometers,* by Elliott, and one by Salleron.

22. *Wiedemann galvanometer*, with two sets of coils and two kinds of needles. Reading by mirror and scale.

23. *Galvanometer* with large wire for experiments on the damping effect of the coils on the needle, and for determining resistances in absolute measure. Designed by Rowland and made by Schneider, instrument maker at the university.

24. *Tangent galvanometer*, wooden circle, with a variety of coils of known constant.

25. *Mirror galvanometer.*

26. *Rowland's wooden circle*, 84 centimetres diameter, carefully laid up out of maple wood, and containing several grooves on the edge to contain single wires. It is used to surround a galvanometer, when, by aid of the electro-dynamometer, the horizontal intensity can be measured at any instant.

27. *Electro-dynamometer* of form given in Maxwell's Electricity, Vol. II, p. 330. Outer circles about 27.5 centimetres diameter, with 240 windings on each side. Constant, G, of outer coils 78.371 on cm. gm. second system. Inner coils about 5.5 centimetres diameter, with 63 coils in each. Moment of inertia of suspended coil accurately known. Constant calculated and also determined by comparison with a tangent galvanometer made of the circle described above. Made (partly) by Gurley, of Troy, and circles wound and measured by Rowland.

28. *Electro-dynamometer*, Quincke's form for weak currents. Made by Edelmann, of Munich.

29. *Standards of resistance*, mounted so that they can be placed in water 1 and 10 ohms, by Elliott; 10, 100, and 1,000 ohms, by Warden, Muirhead & Clark, of London; also mounted in another style—1, 10, and 100 Siemens, units, by Siemens & Halske, of Berlin. Also three copies of coil whose absolute resistance was determined by Rowland as 34.719 *earthquad.* ÷ sec.

30. *Resistance coils* in boxes, 1 to 10,000, and 10,000 to 100,000 ohms, by Elliott, and 1 to 10,000 Siemens' units by Edelmann.

31. *Rowland's resistance comparator.*—Ten coils, of 10 ohms each, arranged so that they can be joined in series or abreast, thus making 1, 10, and 100 ohms, besides intermediate ones. Made by Schneider and adjusted by Rowland.

32. *Two bridges* of Jenkins's form for the accurate comparison of equal resistances, and also a Wheatstone bridge, having wire of platinum-iridium alloy one metre long, by Elliott.

33. *Magneto-electric machine* for 1,200 candles, by Siemens Brothers, London, with engine to drive it, and both Siemens's and Foucault's lamps. Also a battery of 60 large bichromate cells.

34. *Ruhmkorff coil*, spark 15 or 20 centimetres, by Ruhmkorff, of Paris.

35. *Rowland's earth inductor*, with *brass* circle, 30 centimetres diameter, wound and measured by Rowland. Made by Meyerstein, of Göttingen.

36. *Ruhmkorff's apparatus* for diamagnetism. Made by Ruhmkorff, of Paris.

37. *Electric clocks* beating seconds from regulator.

38. *Rowland's standard of electro-magnetic induction.*—Three coils on brass cylinders which can be placed accurately on top of each other. See American Journal of Science. Mutual potential of coils with unit current 3,775,500; 2,561,974; 2,051,320, &c., on the cm. grm. second system.

39. *Telescopes, scales, and mirrors.*—Silvered brass millimetre scale by Brown & Sharp. Mounted telescope by Steinheil, objective 4.0 centimetres diameter, with three oculars, giving powers of 20, 40, and 80. Unmounted telescope by Steinheil, objective 2.7 centimetres diameter, and 3 oculars.

Mounted telescope and paper scale by Meyerstein; objective, 2.7 centimetres diameter.

40. Thin mirrors and plain parallel glasses by Steinheil. The mirrors give a *perfect image with the highest magnifying power.*

Thomson's replenisher on large scale for use with electrometer, Holtz and friction machines, Leyden jar batteries, Geissler tubes, &c.

HEAT.

41. *Rowland's instrument for comparing the mercurial with the air thermometer* between 0° and 100° C. Constructed by Schneider, instrument maker at the university. Readings seldom differ more than 0.02° or 0.03° C. at any one point, especially up to 40° C., and a change is contemplated which will much improve it.

42. *Rowland's instrument for comparing thermometers* from 0° to about 300° C. Constructed by Schneider. Accurate to about 0.1° C.

43. *Regnault's air thermometer*, Golaz, Paris.

44. *Jolly's air thermometer*, by Berberich, Phys. Inst. Univ. of Munich.

45. *Regnault's apparatus for expansion of gases*, both at constant pressure and constant volume, also Regnault's form of Rudberg's apparatus, Golaz, Paris.

46. *Regnault's apparatus for tension of vapors*, including: *a.* The boiler; *b.* The reservoir for compressed air; *c.* A rotary pump for compressing gases; *d.* Mercurial manometer. Maker, Golaz, Paris.

47. *Regnault's apparatus for specific heat* of solids, Golaz, Paris.

48. *Regnault's hygrometer with aspirator*, Golaz, Paris.

49. *Thermometers*, about 30 or 40, principally by Baudin, Paris, and Geissler, of Bonn. Many of these have been compared with the air thermometer as well as with standards by Fastré, Casella, or from Kew. The thermometers up to 40° C. undoubtedly represent the air thermometer more accurately than any so far constructed, and are supposed to agree with it to about 0.01° C. They have been compared with it eight times during about one year or more. The error in calorimetric investi-

gations from using uncompared thermometers *may* amount to two per cent.

50. *Rowland's apparatus for determining change of specific heat of liquids* with temperature. Constructed by Schneider.

51. *Dulong's apparatus for the heat of combustion*, Salleron, Paris.

52. *Melloni's apparatus* for radiant energy, Salleron, Paris.

53. *Two instruments for the calibration* of mercurial thermometers, one by Golaz and the other by Salleron.

54. *Rowland's apparatus for determining the mechanical equivalent of heat*, or for investigating the specific heat of liquids and their change with rise of temperature.

This instrument was constructed by the aid of funds contributed by the Rumford committee of the American Academy of Arts and Sciences, but the instrument will remain for the present at Baltimore. It was constructed by Schneider. It is run by a petroleum engine, No. 66 below.

To be constructed soon:*

Apparatus for compressing gases to 1,000 atmospheres.

Apparatus for *accurately* determining the form of the adiabatic curve of gases and vapors *at any temperature up to about* 100° C.

MISCELLANEOUS.

55. *Comparator*, by Meyerstein, for bars 1 metre long. Microscopes cannot be set nearer than 10 centimetres. One division of head of micrometer screws is about 1-700 millimetre.

56. *Microscope comparator*, designed by Rowland after Rogers's plan, and made by Grunow.

57. *Dividing engine*, by Perreaux. Free motion about 55 centimetres. Screw, ½ millimetre thread. Head divided into 250 parts. 5.1 divisions of head gives 1 millimetre almost exactly. Subsidiary screw at right angles to other one.

58. *Air pumps.*—Rotary and common, by Ritchie, of Boston; mercury, on Jolly's plan, by Berberich, of Munich.

59. *Rotary pump* for compressing gases to 15 atmospheres. Golaz, Paris.

60. *Three mercury gauges*; one about 25 metres high, and measuring pressures up to about 33 atmospheres; one movable and measuring pressure from 1 to 4 atmospheres; and one measuring from 0 to 1 atmosphere.

61. *Barometer*, by James Green, of New York, with very large tube.

62. *Two cathetometers*; one by Meyerstein and the other by Salleron.

63. *Standard metres*, compared at Washington.

64. *Balances and weights.*—One balance weighing to 5 kilos. and accurate to about 1 mg., with weights from 5 kilos. to 1 mg. One weighing to 200 grms. accurate to about 0.1 mg., with weights from 100 grs. to 1

*Nos. 18, 24, 25, and 27, and the silvered scale of No. 39, belong to Professor Rowland, but are used in the laboratory.

mg. These are by Schickert, of Dresden. One heavy balance weighing to about 25 kilos. and accurate to about 0.1 grm., by Schneider.

Standard glass kilogramme on Jolly's plan, and compared with Berlin standard. From Berberich, in Munich.

The first balance mentioned is mounted on top of a case, so that globes for weighing gases can be suspended beneath it.

65. *Clock-work* with Foucault's regulator for running small apparatus at a regular velocity.

66. *Petroleum engine* of three-horse power. It is capable of giving a large amount of compressed air at more than 100 pounds to the square inch pressure, and might be used for repeating Thomson's and Joule's experiments or any others on the flow of gases.

67. *Two spherometers*; large by Meyerstein, and small by Salleron.

68. Several extra micrometer eye-pieces.

69. *Apparatus for researches on the flow of liquids.*—Greatest available head about 1.4 metres.

BIOLOGICAL LABORATORY.

(In charge of Professor H. N. MARTIN.)

Apparatus for exact measurements.

1. *Pendulum myographion*, modified from Fisk's; available for the measurement and analysis of rapid movements. The instrument consists essentially of a pendulum carrying a glass plate at the bottom, swinging on friction rollers, and corrected for the latitude of Baltimore, so as to swing in one second. Behind the pendulum is a divided arc, and the amplitude of the swing can be varied from a few inches to four feet. In use an electro-magnet is moved along the divided circle, and then—the current being closed through it—the pendulum, on being raised, is held by it. On the other side is a catch, also movable along the arc. By turning a key at the side the current in the electro-magnet is broken, and the pendulum swings across and is held by the catch on the other side. During its transit the movement to be analyzed is inscribed on the glass plate, which is previously smoked. Designed by A. G. Dewsmith, esq., Trinity College, Cambridge, England. Made by Elliott, London.

2. A set of three pairs of König's recording tuning forks for measuring small periods of time; giving respectively 50, 100, and 200 double vibrations per second.

3. Bernstein's differential rheotome, with Helmholtz's electromotor to drive it. Zimmermann, Heidelberg.

4. Two Sir William Thomson's reflecting galvanometers; one large and the other small resistance. Elliott, London.

5. *Ludwig's kymographion;* to give uniform horizontal movement to an endless sheet of paper, on which vertical movements can be recorded and subsequently measured and analyzed. The instrument is provided

with an electro-magnetic chronograph. Made by Fulcher, Cambridge, England.

6. *Kymographion.*—Modification of the above. Made by Warden, Muirshead & Black, London.

7. "*Signal*" of Deprez. Electro-magnetic chronograph, recording up to 250 double vibrations per second.

8. *Chronograph* of Masey. Similar to above, recording to one-hundredth of a second.

9. *Spectroscope*, one prism, by Browning, London.

10. *Wild's Polaristrobometer.*—Schmidt & Haensch, Berlin.

11. *Completely fitted microscope*, by Zeiss, Jena. With microspectroscope and polarizing apparatus.

12. *Seconds clock with electric attachment.* Elliott, London.

CONDENSED LIST OF APPARATUS IN SMITHSONIAN INSTITUTION.

1 Shaw's testing machine.
1 Gaiffe's induction coil and battery.
1 Varley's resistance coil.
6 Ruhmkorff's galvanometers.
1 electrometer.
2 Holtz electrical machines.
3 Soleil's polariscopes.
1 Hall's spectroscope.
1 heliostat.
1 telescope, with rock salt objective.
14 radiometers.
1 phonautograph.
1 Koenig's chronograph.
2 electrical interrupters.
1 set Koenig's acoustical apparatus.
1 Hough's barograph.
1 Green's siphon barometer.
2 Casella's sensitive hygrometers.
1 magnesium lamp.
Miscellaneous optical, electrical, and meteorological apparatus.

ORNITHOLOGICAL EXPLORATION OF THE CARIBBEE ISLANDS.

By F. A. Ober.

The first week in December, 1876, I left New York in a small vessel for Martinique, situated in latitude 15° N. The usual passage is less than twenty days, but, owing to unskillful navigation, our vessel was stranded on the Bomunda reefs, and we were detained a month for repairs, not reaching Martinique until January 25, 1877. Learning that the island of Dominica, 30 miles to the northward, would be likely to give better results than Martinique, I sailed for that island in a small native sloop, landing at Roseau, the principal town, the 1st of February. Owing to unavoidable delays I did not reach any important collecting ground until the 1st of March, thus losing the first two months of the year in which fine weather generally prevails.

To properly understand the *fauna* of the Caribbean group, it should be borne in mind that, between the degrees of 12° and 18° north latitude, all the principal islands, except Antigua and Barbuda in the north, and Barbados away to the eastward, are volcanic, consisting mainly of high hills and mountains. The general resemblance strikes one forcibly as he sails along this chain of islands; each one like a huge rock thrown up from the ocean depths, terminating either in a single peak or split into a succession of mountain peaks and hills. In Dominica is the highest mountain south of Jamaica, in the West Indies, "Monte Diablotin," being above 5,000 feet in height. A slight sketch of the prevailing characteristics of the vegetation of this island will answer for all the volcanic islands.

There are, as it were, three zones or belts of vegetation, viz: that of the coast; that of the higher hills and lower mountains; that of the mountain tops. The first-named contains the plantations, upon which are found but few birds of any kind, owing to the absence of trees. The second contains all that is luxuriant in tropical vegetable life, and is especially peculiar in being the zone in which are first found the tree ferns and the forest of huge trees known as the "high woods." It may be roughly estimated as located between 500 and 2,500 feet above sea-level. Where an opening occurs for the sun to penetrate, animal life will be found more abundant than in the lower region. This I soon ascertained, and established myself in an opening in the forest where a sloping strip of land had been cleared of trees, about 1,500 feet above the Caribbean Sea, which it overlooked at a distance of about five miles. This slope had been cleared by the ancestors of some half a dozen families of French colored people, and was planted fifty years ago with coffee trees; but now was overgrown with grass and wild trees. On all sides were high hills covered with the almost impenetrable forest. As the only collector who had visited this or any other island had not visited the mountains, but had merely examined the shore and the easily reached cultivated valleys, I knew my attention would be better directed to the wilderness, and that my only opportunity for rare or new birds would be among the half-civilized people of the mountains. The results have shown the correctness of my plans, and have been fully shown in the several catalogues prepared by Mr. Lawrence, from my notes and collections. In this region I obtained not less than five new species and two new varieties: The *Thryothorus rufescens*, *Dendrœca plumbea*, *Myiarchus oberi*, *Vireosylvia calidris* var. *dominicana*; *Chaetura dominicana*, *Blacicus brunneicapillus*, and, later, in September, the *Strix flammea* var. *nigrescens*. As the more extended notes of my collections are already in manuscript for the catalogues and some already published, I will not refer to them here.

In April I returned to the coast, and, having left my specimens (200 in number) with a friend, to be sent to the States, started again for another part of the island, over the mountain ridges to the Atlantic coast, among the Caribs. It is a two days' journey, as I had to take it on foot, and several rapid swollen streams had to be crossed. All my baggage was carried upon the heads of my mountaineer friends, of whom I had four, three girls and a man. At the last house before reaching Indian country, five miles distant, I was hospitably entertained by the planter, who also secured me a comfortable hut from the natives.

As my space is here limited, I can do no more than rapidly sketch what would require many pages of description. Suffice it to say, that I found the Caribs of to-day different from the *Charaibs* of one hundred and fifty years ago, as described by Père Labat. They speak a French *patois* and are good Catholics, and through the influence of the French priests, who make them monthly visits, they have been compelled to intermarry with negroes to such an extent that the individuality of the Carib is gone. There are not more than twenty families of uncontaminated blood in the island. These, with a few in St. Vincent, comprise *the whole* of the remainder of the many thousands found in these islands by Columbus. A few old men and women only can speak the ancient Carib tongue; from these I obtained a good vocabulary, which, by comparing with another I secured in St. Vincent, I found to be correct. The Caribs are more peaceful citizens than the negro, more cleanly and intelligent, but not a whit more industrious or virtuous. They subsist by fishing and cultivating provision grounds in the mountains, but very few of them follow the chase. I remained with them six weeks, secured many valuable photographs, and many notes respecting them of value to the ethnologist and philologist. I was prostrated by fever upon my return to

Roseau, and passed the period of convalescence on the Caribbean coast, procuring, in my intervals of strength, the birds breeding in the cliffs. It was in the Atlantic Mountains that I procured the first specimens of the Imperial Parrot (*Chrysotis angusta*) ever sent to America.

The 4th day of July, 1877, I arrived at Antigua, in latitude 17° north, and examined that island, and also Barbuda, 30 miles farther north. These islands are of different formation from the others of the chain, though owing their origin, perhaps, to the same cause. The rocks of the western portion of the island, according to Davies, are of igneous character, denoting violent action and protrusion from beneath, akin to the volcanic, but without actual eruption or explosion. Eastern rocks belong to the "tertiary aqueous formation, being chiefly calcareous freestone and limestone, containing organic remains." "In the intermediate space are exhibited both igneous and aqueous action; the former in the indurated clays and siliceous cherts, forming the skirting western declivities; the latter in the numerous petrifactions, varieties of wood or coral, principally, if not entirely, siliceous." In Barbuda are many deer, wild guinea fowl, and horses, the result of stock introduced from England many years ago.

In Antigua I found one species of owl, since declared to be *new*, the *Speotyto amaura*, but few birds of any kind. In September large flocks of plover, and in October teal and duck, visit this island in large numbers. Its full *avi-fauna* will be found in the catalogue recently prepared by Mr. Lawrence from my notes.

In September, I sailed for St. Vincent, stopping two weeks, on my way south, at Dominica, to procure further specimens of the species declared new and rare by letter from Mr. Lawrence. I was there fortunate in securing the owl since identified as a local variety of *Strix flammea*, with three eggs. Two specimens were shot, male and female. Reaching St. Vincent in October, I early set to work, but was hindered by the rains. I not only searched all around the coast, but penetrated to the mountains. Here I was peculiarly fortunate, securing *seven new species*. The names, as appearing in the catalogue of the birds of St. Vincent, since published, are as follows: *Turdus nigrirostris*, *Myiadestes sibilans*, *Thryothorus musicus*, *Certhiola atrata*, *Certhiola saccharina*, *Leucopeza bishopi*, *Calliste versicolor*. My adventures in securing the *Myiadestes sibilans* were most interesting. I found that the only way to reach it was to camp upon the crest of the crater of the volcano, which I did, making my home in a cave for five days and nights, 3,000 feet above the sea. It rained continually during my stay, in my exposure to which I contracted a severe cold which culminated in a fever several weeks later. I had the exquisite pleasure, however, of securing there the wonderful bird named above, known to the natives as the "invisible souffriere bird." Barely a hint of the existence of this bird is contained in scientific annals, and that only in Goss's Birds of Jamaica, in a letter to the author of that work.

The Rev. Lansdowne Guilding, a clergyman residing in St. Vincent at that period, made many unsuccessful endeavors to procure it, and it was an object of search for fifty years. It was left for an American, however, to settle the doubt hovering over its identity, and to establish the fact that it is a separate species, and, what is of greater interest, a *new* one.

The proudest moment of my life, I think, was that in which I held the first specimen of that bird in my hand, after two days' search and the use of all my arts of allurement as taught me by my Carib friends. With the specimens of this genus, and the related genera of Dominica and Martinique, obtained by me, I feel assured that all doubts regarding their affinity may be set at rest. I secured six specimens of this bird, and at the same place and time the new species which they have done me the honor to name for my friend Nathaniel H. Bishop, the famous canoe voyageur. From the volcano I descended to the eastern slope, and passed three weeks with the Caribs there. Many photographs and much valuable matter relating to their traditions and language were obtained, but I could not secure such a series of their former implements of agriculture and warfare as I desired, owing to the same reason as in Dominica: the mountainous character of the island giving hiding-place to thousands of objects that in a flat country would be easily found, even after the lapse of centuries.

From the Carib country I returned to the west coast in a Carib canoe. In December, 1877, I again crossed the souffriere or volcano, and took up my line of investigation, to complete the circuit of the island. In this trip I procured two species of that rare and beautiful parrot, the *Chrysotis guildingi*.

In February, 1878, having recovered from my fever, I explored one of the northern grenadines, where I found in a cave an elegantly carved *tortoise* of wood. In this trip I also shot the first specimens of the blackbird, afterwards obtained in Grenada, pronounced *new*, the *Quiscalus luminosus*. These were lost through the wrecking of our boat. In St. Vincent I photographed and sketched two rocks which tradition affirmed were sacrificial rocks of the Caribs, containing incised figures upon them, fast being obliterated. A carefully drawn reproduction of this photograph will be forwarded with my detailed description. There is a larger rock of similar character in Guadaloupe.

I reached Grenada, the southernmost of the volcanic chain, in latitude 12° north, early in March, and at once proceeded to the interior of the mountains. There, in the high woods surrounding the famous mountain lake or "*grand etang*," I procured the wren, since named (*new*) *Thryothorus grenadensis*, and two other birds from the coast, *Quiscalus luminosus* and *Turdus caribæus*, three new species in all. Grenada is the only island containing the armadillo, and one of three only containing monkeys.

In the fauna of Grenada I was much disappointed; hoping to find many new and tropical species from Trinidad and the mainland of South

America, less than 100 miles away. Instead I found that there were fewer resident species than in the more northern (mountainous) islands, and but a hint afforded here and there of species I later found abundant in Tobago, and belonging to the continental fauna. This subject is spoken of more at length in my introduction to the Grenada catalogue. In April I sailed for Tobago, an island out of the route allotted me, but one containing valuable species, and the study of which, in connection with my previous observations in the Antilles proper, was imperatively necessary. In this island I brought to light many new facts regarding the early correspondence and discoveries of Mr. Kirk, the friend and collector of Sir W. Jardine, forty years ago.

Leaving Tobago I arrived in Barbados the last of June, and at once proceeded to Martinique, in which island I remained seven weeks. Martinique and Guadaloupe have both been well investigated, and I do not anticipate anything of value from these islands. Regarding the range of the "*Siffleur montagne*," or "mountain whistler," found also in Dominica, I consider my notes of value, and also relating to a few others. Here I encountered much trouble from the terrible serpent peculiar to that island and St. Lucia, the *Craspedocephalus lanceolatus*, two specimens of which, in rum, I sent to the museum.

In August I sailed for Guadaloupe, reaching the mountains the last week in that month. Here, though I do not expect there are any new birds among my collections, I procured some very rare ones, among which was the *Tappeur* or woodpecker—the only one found in the Caribbee Isles and not found in any other—the *Picus l'herminieri* of Lesson. Also the *Perdix croissant*, a dove peculiar to this island, the *Geotrygon mystacea*. Three of this species I brought home alive to Mr. Lawrence. Regarding the almost mythical *Diablotin*, the *Procellaria diabolica*? of L'herminier, I procured notes of interest. In Guadaloupe, as in Martinique, there is an excellent museum called the *Musée de L'herminier*. Nearly all the valuable collections of the late Dr. Lherminier were destroyed in the great fire that ravaged Point à Pitre a few years ago. Though the doctor discovered many new species here, some of the types of which he sent to France, and some of which (I think) are in the *de la Fresnaye* collection in Boston, none of his original notes are extant. I was told that they perished with his collections in the conflagration.

Leaving Guadaloupe in October, 1878, I arrived in New York, after a tempestuous passage, to find that of all the specimens shipped to the museum at different times, not one was lost. It will be seen that in ornithology alone my collections contained *eighteen species and varieties new to science*, a result that cannot fail to be considered gratifying. There yet remain (at this present writing, December) the collections from Martinique, Guadaloupe, and Tobago unexamined.

Fortunate as I have been, I cannot but regret that the appropriations for finishing my search and completing a work but little more than half accomplished were not forthcoming. All my private funds and all fur-

nished me by the Institution were exhausted when I was obliged to return. Another year to study the many problems, which require time for their solution, would, with the information now in my possession, add greatly to what has already been obtained, and give to our National Museum the first series of types, complete, of the *Birds of the Lesser Antilles.*

REPORT OF EXPLORATIONS IN GREENLAND.

By L. Kumlein.

The Florence sailed from New London harbor August 2, 1878. The general equipment was good, but some important items had been overlooked, which occasioned the scientific department much inconvenience.

The first harbor made was at Niantilic in Cumberland Gulf, after a passage of forty-one days. The prevailing winds were easterly and light, with much fog. Off Resolution Island a heavy northeast gale was encountered which stove one boat and did other damage. The ground was covered with snow on our arrival and it looked gloomy. The stay in Niantilic was short; having procured some Eskimo we set sail for the opposite shores of the gulf, and then for the North. Arrived in Annanatook harbor (the head of Cumberland Gulf) October 7, 1878. Arrangements were immediately made for an observatory, consisting of a canvas tent, around which a hut of snow was built. In this illy-lighted and poorly-warmed structure Mr. Sherman and myself spent our time till July.

During the winter we could procure *Pagomys fœtidus* at almost any time. This is by far the most common seal in Cumberland and the principal food of the Eskimo. *Phoca barbata* is only procured when there is open water, as they do not have breathing-holes in the ice. *Phoca cristata* was rare. *Callocephalus vitulinus* is often taken by the Eskimo in the salmon fjords. *Pagophilus grœnlandicus* common during open water. *Trichecus rosmarus* is common around Cape Mercy and on the opposite shores, but now not found at the head of the gulf, though their remains are common. Reindeer could be procured at any time a short distance from the coast inland, and even on the islands in winter. *Lepus glacialis* is quite common in some localities, but only two were obtained at our winter harbor. *Canus occidentalis* are met with in roving bands where the reindeer are the most common. *Vulpes lagopus* everywhere, but most plenty where there are numbers of hare and ptarmigan. *Ursus maritimus* is no rarity about Cape Mercy and the mouth of the gulf, but very rarely seen in the upper fjords. A single lemming was procured, and but two *Mustela.* Cetaceans of many species were common, especially so *Delphinapterus lucas* (of which a fine skeleton was procured), and their dreaded enemies *Orca gladiator.* An excellent series of skins, skeletons, and skulls of *Phoca fœtida* were secured; they range from a 6-inch fœtus to the adult of 5 feet. Studies were attempted on the diseases of the

Eskimo dog, and good points were ascertained. While dissecting one of these animals I had the misfortune to cut a finger slightly, and the virus (?) together with a frost-bite made me a cripple for two months, and came very near costing me the loss of my arm; this occurring in my busiest season, I lost many specimens. Eskimo women were instructed to skin and clean birds and mammals, which they soon learned to do very nicely, invariably removing the fat with the teeth. The greatest cold was in January—52°.5. From the 27th of February to March 18 the temperature did not rise above 35°. The heaviest snow-fall was in June. During the latter part of June the winds were southerly, driving the ice in a compact mass towards the head of the gulf so that it was nearly impossible to make any excursions away from the ship. No birds except *Corvus corax*, *Falco candicans*, and two species of *Lagopus* remain during the winter. The first birds to return are *Larus glaucus*, often long before there is any open water; they cruise up the ice-covered fjords and feed on the young of *Phoca fœtida.* As soon as the snow begins to melt *Plectrophanes nivalis* greets one with a very pretty song. Eiders, *Somateria mollissima*, nested by thousands on the rocky islets around our winter harbor, and the eggs were a very welcome addition to our rations. Some rare eggs were procured, among them *Tringa subarquata*, *Stercorarius pomatorhinus*, and *parasiticus Haliastus albicilla.*

Some Pacific species were added to the fauna of the Atlantic seaboard, and some birds of N. temperate North A. were found breeding to 68° 30′ N. Specimens were procured of *Pagophila eburnea*, *Buphagus skua Larus glaucescens*, and *leucopterus*, &c. The fauna seemed to be nearly identical with that of north Baffin's Bay. Only forty-two species of birds were met with in Cumberland Sound, and of these four at least were stragglers. Interesting notes were procured on rare or little-known Arctic water-birds.

Some fossils were procured from Lake Kennedy and some interesting minerals. We left much too early to secure a fair representation of the flora of the district, poor as it is. The same species were collected on the Greenland coast in 70° 30′, much more luxuriant. The algæ could not be collected in the spring on account of the ice around the shores. They were abundant both in species and numbers, some of them remarkably large.

Some interesting notes on the habits, legends, &c., of the Eskimo were secured with drawings; also a good number of Eskimo drawings, which are very interesting.

Eskimo implements few, but still some very valuable forms were found. Great difficulty was experienced in getting the Eskimo to part with implements in use; even a considerable reward would not induce them to part with some things. The vicinity of Annanatook (our winter harbor) was a most remarkably barren place, bare granitic islands with steep bluff shores offering no place to collect marine life even at low tide. Notes of value were obtained on the distribution of mammals and birds. Fishes were rare; we could only get two kinds in sufficient numbers to use as food—*Cottus scorpius* and *Salmo salar*. Other species were collected, but very few specimens. Did not get out of Cumberland Gulf till the 19th of July. We then took the pack-ice off Cape Mercy, and with strong east winds worked through 250 miles of it. Reached Godhavn Harbor on the last day of July. We had expected to meet the government expedition here, and had fifteen Eskimo, thirty dogs, clothing, and a vast amount of material requisite for a Polar expedition. We waited here till the 22d of August, and then set sail to return the Eskimo to their native place. During our stay in Godhavn we were greatly aided in our researches by Governor E. Fincker and Inspector K. Smitz, who did all in their power to make our stay pleasant, besides giving us much valuable information and many specimens. The ice in Baffin's Bay was the heaviest ever known to the Danish traders. No vessels, even the large Dundee steam-whalers, were able to get out of the Waigal Straits, nor could the Danes get to the Upernavik settlements. While returning to Cumberland we experienced a tremendous southeast gale which lasted nearly four days. When it abated we found our ship in the mouth of Exeter Sound, on the opposite shore of Davis' Straits, from where we had started.

During these four days we drifted at the mercy of the winds and waves among hundreds of icebergs, but received no damage to speak of. The Eskimo were landed and given some presents on the last of August. On the 12th of September we set sail for home, arriving at St. John's, Newfoundland, on the 26th, after a very stormy passage. On the 11th of October we sailed from St. John's. From this time till we reached Provincetown, Mass., we rode out six heavy gales of wind. The ship sprung a leak off Sable Island, and gave us much work and anxiety. Our provisions also became rather short, so we were put on allowance, and a very small allowance at that. I must not forget to mention that I used only a Remington breech-loading shot-gun, and that it did not fail me on a single occasion, though subjected to every kind of ill-treatment

RESEARCHES IN SOUND:

WITH SPECIAL REFERENCE TO FOG-SIGNALING.

BY JOSEPH HENRY.

[FROM THE ANNUAL REPORTS OF THE U. S. LIGHT-HOUSE BOARD.]

PREFATORY NOTE.

[The series of investigations undertaken by the late Professor Henry in the interest of the light-house service, embracing not only observations more than usually laborious and extended, with regard to the atmospheric conditions affecting the propagation of sound to a distance, but varied and elaborate experimental inquiries, as well, with reference to the most efficient character and form of sonorous instruments for fog-signaling purposes, commenced as far back as the year 1865, and continued to the last year of his life.

These important investigations, though in the language of an official report, they "have resulted in giving us a fog-signal service conceded to be the best in the world,"* have hitherto received so little publicity and attention, owing to the purely official character and channel of their presentation, that their collection and republication here (in advance of of a possible edition of Henry's collected works), appears to be called for in the interests of science, as well as of a just appreciation of the value of his prolonged researches.

The first part, extracted from the Appendix to the Light-House Report for 1874, comprises a preliminary statement and an account of observations and experiments made by the author, from 1865, at New

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*Executive Document No. 94, Forty-fifth Congress, second session, Senate, p. 2. This is a report to the Hon. Secretary of the Treasury, made since Professor Henry's death. To a similar effect, may be quoted an official statement made five years earlier. In 1873, Major George H. Elliot, of the Light-House Board, commissioned to make a tour of inspection of European light-house establishments, presented the results of his observations abroad in a very able and elaborate report, published by the Senate in 272 octavo pages, with numerous illustrations. In his preliminary report to the Board, dated September 17, 1873, he concludes, that while there are "many details of construction and administration which we can adopt with advantage," (from the British and French light-house systems,) "there are many in which we excel. Our shore fog-signals, particularly, are vastly superior, both in number and power." (Executive Document No. 54, Forty-third Congress, first session; Senate, p. 12.)

Haven, Conn., to 1872, at Portland, Me. The second part is a communication made to the "Philosophical Society of Washington" (of which he was the president) December 11, 1872, embracing a discussion of some abnormal phenomena of sound, and is extracted from the Bulletin of the Society, vol. ii, appendix ix. The third part, forming the latter portion of the Appendix to the Light-House Report for 1874, comprises investigations extending from 1873, at Whitehead Station, off the coast of Maine, to 1874, at Sandy Hook, New Jersey. The fourth part, extracted from the Appendix to the Light-House Report for 1875, comprises his investigations for that year. And the fifth part, from the Appendix to the Light-House Report of 1877, embraces his latest observations during September and October of the year 1877.

These papers necessarily are more fragmentary, and at the same time involve more recapitulation than would have been the case, could they have received the revision of their distinguished and lamented author. It has however been considered more just to reproduce these contributions in this form, than to attempt either a compilation of extracts, or a condensation of their substance in the form of an abstract.]

S. F. BAIRD.

RESEARCHES IN SOUND.

INTRODUCTION.*

FOG.

Among the impediments to navigation none perhaps are more to be dreaded than those which arise from fogs, and consequently the nature of this impediment and the means which may be devised for obviating it are objects of great interest to the mariner. Fogs are in all cases produced when cold air is mingled with warm air saturated with moisture. In this case the invisible vapor of the warmer air is condensed by the cold into minute particles of liquid water, which, by their immense number and multiplicity of reflecting surfaces, obstruct the rays of light in the same way that a piece of transparent glass when pounded becomes almost entirely opaque and is seen by reflection as a white mass. So greatly does a dense fog obstruct light, that the most intense artificial illumination, such as that produced by the combustion of magnesium, by the burning of oxygen and hydrogen in contact with lime, and that produced between the charcoal points of a powerful electrical apparatus, are entirely obscured at comparatively short distances. Even the light of the sun, which is far more intense than that of any artificial illumination, is so diminished by a single mile of dense fog that the luminary itself becomes invisible. Recourse must therefore be had to some other means than that of light to enable the mariner to recognize his position on approaching the coast when the land is obscured by fog.

The only means at present known for obviating the difficulty is that of employing powerful sounding instruments which may be heard at a sufficient distance through the fog to give timely warning of impending danger. Investigations therefore as to the nature of sound and its applications to fog-signals become an important object to those in charge of aids to navigation. Such investigations are of special importance in connection with the light-house service of the United States. The northeastern coast of the United States on the Atlantic, and the entire western coast on the Pacific, included in our territory, are subject, especially during the summer months, to dense fogs, which greatly impede navigation, as well as endanger life and property.

The origin of the fogs on our coast is readily explained by reference to a few simple principles of physical geography. In the Atlantic Ocean there exists a current of warm water proceeding from the Gulf of Mexico, between Cuba and Florida, which flows along our coast to the lati-

* From the Report of the Light-House Board, for 1874.

tude of about 35°, and then turning gradually to the eastward, crosses the Atlantic and impinges against the coast of Northern Europe. Throughout its entire course, on account of the immense capacity of water for heat, the temperature of the stream is greater than that of the ocean on either side. In addition to this stream, the Atlantic Ocean is traversed by another current of an entirely opposite character, one of cold water, which, coming from the arctic regions down Davis's Strait, is thrown, by the rotation of the earth, against our coast, passing between it and the Gulf-stream, and sinking under the latter as it approaches the southern extremity of the United States.

These conditions are those most favorable to the production of fogs, since whenever the warm air, surcharged with moisture, is blown from the Gulf-stream over the arctic current and mingles with the cold air of the latter, a precipitation of its vapor takes place in the form of fog. Hence, especially in summer, when the wind in the eastern part of the United States is in a southeasterly direction, fogs prevail. As we proceed southerly along the coast, the fog-producing winds take a more easterly direction.

A somewhat similar circulation in the Pacific Ocean produces fogs on the western coast of the United States. In this ocean a current of warm water, starting from the equatorial regions, passes along the shores of China and Japan, and, following the general trend of the coast, turns eastward and continues along our shore. The northern part of this current being warmer than the ocean through which it passes, tends to produce dense fogs in the region of the Aleutian Islands and the coast of Alaska. As this current descends along the American coast into lower latitudes it gradually loses its warmth, and soon assumes the character, in regard to the water through which it passes, of a comparatively colder stream; and to this cause we would attribute the prevalence of fogs on the coast of Oregon and California, which are most prevalent during the spring and early summer, with wind from the northwest and west.

From what has been said, it is evident that the fogs in the Aleutian Islands occur chiefly in summer, when southwesterly winds prevail and mingle the moist air from the warm current with the colder air of the more northerly latitude. In winter, the wind being from the north chiefly, the moist air is driven in an opposite direction, and dense fogs therefore at this season do not prevail.

In regard to the fogs on the coast of Maine, the following interesting facts were furnished me by the late Dr. Stimpson, formerly of the Smithsonian Institution and of the Chicago Academy of Sciences, who had much experience as to the weather during his dredging for marine specimens of natural history in the region of Grand Manan Island, at the entrance of the Bay of Fundy.

"So sharply marked," says Dr. Stimpson, "is the difference of temperature of the warm water from the Gulf-stream and that of the polar current, that in sailing in some cases only a few lengths of a ship the temperature of the water will change from 70° to 50°. The fog frequently comes rolling in with the speed of a race-horse; in some cases while dredging, happening to turn my eyes to the south, a bank of fog has been seen approaching with such rapidity that there was scarcely time in which to take compass-bearing of some object on shore by which to steer, before I would be entirely shut in, perhaps for days together." He also mentions the fact that it frequently happened during a warm day, while a dense fog existed some distance from the shore, close in to the latter there would be a space entirely clear; this was probably due to the reflection and radiation of the heat from the land, which converted the watery particles into invisible vapor.

Dr. Stimpson has also noticed another phenomenon of some interest. "When a dense fog, coming in regularly from the sea, reaches the land, it gradually rises in the atmosphere and forms a heavy, dark cloud, which is frequently precipitated in rain." This rising of fog is not due, according to the doctor, to a surface-wind from the west pressing under it and buoying it upward, since the wind at the time is from the ocean. It is probably due to the greater heat of the land causing an upward current, which, when once started, by its inertia carries the cloud up to a region of lower temperature, and hence the precipitation. The height of the fog along the coast is not usually very great, and can be frequently overlooked from the mast-head. The deception as to size and distance of objects as seen in a fog is also a remarkable phenomenon when observed for the first time. A piece of floating wood at a little distance is magnified into a large object, and after much experience the doctor was not able to overcome the delusion. It is said that the sailors in the Bay of Fundy prefer of two evils a fog that remains constant in density to one that is variable, although the variation may be toward a greater degree of lightness, on account of the varying intensity producing a varied and erroneous impression of the size and distance of the object seen through it. It is also his impression that sound can be heard as well during fog as in clear weather, although there is a delusion even in this, since the source of sound, when seen, appears at a greater distance than in a clear atmosphere, and hence the sound itself would appear to be magnified.

Fogs also exist on the Mississippi, especially on the lower portion of the river. They are of two classes, those which result from the cooling of the earth, particularly during the summer in clear nights, with wind probably from a northerly direction, followed by a gentle, warm wind from the south surcharged with moisture, and the other induced by the water of the river, which, coming from melting snow of northern regions, is colder than the air in the vicinity. The air over the river being thus cooled below the temperature of a gentle wind from the south, the moisture of the latter is precipitated. This fog, which occurs in the last of winter, during the spring, and beginning of summer, is very dense, but is confined entirely to the atmosphere above the river, while the other class of fog exists over the land as well.

FOG-SIGNALS.

The importance of fog-signals as aids to navigation, especially on the northeastern portion of our coast, of which the shore is exceedingly bold and to the approach of which the sounding-line gives no sure indication, has been from the first an object of special attention.

At the beginning of the operations of the Light-House Board such instruments were employed for producing sound as had been used in other countries; these consisted of gongs, bells, guns, horns, &c. The bells were actuated by clock-machinery, which was wound up from time to time and struck at intervals of regular sequence by which their position might be identified. The machinery, however, by which these bells were struck was of a rude character and exceedingly wasteful of power, the weight continuing to descend during the whole period of operation, including the successive intervals of silence. This defect was remedied by the invention of Mr. Stevens, who introduced an escapement arrangement, similar to that of a clock, which is kept in motion by a small weight, a larger one being brought into operation only during the instant of striking.

Bell-buoys were also introduced at various points. These consisted of a bell supported on a water-tight vessel and rung by the oscillation of the waves, but all contrivances of this kind have been found to be untrustworthy; the sound which they emit is comparatively of feeble character, can be heard at but a small distance, and is frequently inefficient during a fog which occurs in calm weather. Besides this, automatic fog-signals are liable to be interfered with by ice in northern positions, and in all sections to derangement at times when no substitute can be put in their place, as can be in the cases of the bells rung by machinery under the immediate control of keepers. A signal which is liable to be interrupted in its warnings is worse than no signal, since its absence may give confidence of safety in the midst of danger, and thus prevent the necessary caution which would otherwise be employed.

Guns have been employed on the United States coast, first under the direction of General Bates, engineer of the twelfth district, at Point Bonita, San Francisco Bay, California. The gun at this station consisted of a 24-pounder, furnished by the War Department. The necessary arrangements being made, by the construction of a powder-house, and laying of a platform, and employment of a gunner, notice to mariners was given that after the 8th of August, 1856, a signal-gun would be fired every hour and half-hour, night and day, during foggy or thick weather. The first year, with the exception of eighty-eight foggy days, omitted for want of powder, 1,390 rounds were fired. These consumed 5,560 pounds of powder, at a cost of $1,487, pay of gunner and incidentals excluded. The following year the discharges were 1,582, or about one-eleventh of the number of hours and half-hours of the whole time. The fog-gun was found to answer a useful purpose; vessels by the help of it alone having come into the harbor during a fog at night, as well as in the day, that otherwise could not possibly have entered. This signal was continued until it was superseded by a bell-boat. A gun was also used at West Quoddy Head, near the extreme eastern part of Maine. It consisted of a short piece, or carronade, 5 feet long, with a bore of 5¼ inches, charged with four pounds of blasting-powder. The powder was made up in cartridges and kept in chests in the work-house. The gun was only fired on foggy days, when the steamboat running between Boston and Saint John, New Brunswick, was approaching the light-house from the former place. In going in the other direction the signal was not so much required, because in the former case (of approach) the vessel had been for some time out of sight of land, and consequently its position could not be so well known. The firing was commenced with the hearing of the steamer's whistle as she was approaching, and as the wind during the fog at this place is generally from the south, the steamer could be heard five or six miles. The firing was continued as frequently as the gun could be loaded until the steamer answered by a signal of three puffs of its whistle. The number of discharges was from one to six, the latter exhausting a keg of powder valued at $8. The keeper of the light-house acted as gunner, without compensation other than his salary. The cost of powder was paid by the steamboat company. The report of the gun was heard from two to six miles.

This signal has been abandoned,—because of the danger attending its use,—the length of the intervals between the successive explosions,—and the brief duration of the sound, which renders it difficult to determine with accuracy its direction.

The lamented General Bache, of the Light-House Board, adopted a very ingenious plan for an automatic fog-signal, which consisted in taking advantage of a conical opening in the coast, generally designated a blow-hole. On the apex of this hole he erected a chimney which terminated in a tube surmounted by a locomotive-whistle. By this arrangement a loud sound was produced as often as a wave entered the mouth of the indentation. The penetrating power of the sound from this arrangement would not be great if it depended merely on the hydrostatic pressure of the wave, since this, under favorable circumstances, would not be more than that of a column of water 20 feet high, giving a pressure of about 10 pounds to the square inch. The effect however of the percussion might add considerably to this, though the latter would be confined in effect to a single instant. In regard to the practical result from this arrangement, which was continued in operation for several years, it was found not to obviate the necessity of producing sounds of greater power. It is however founded on an ingenious idea, and may be susceptible of application in other cases.

EXPERIMENTS BY PROFESSOR ALEXANDER, IN 1855.

The Light-House Board was not content with the employment alone of the fog-signals in ordinary use, but directed a series of experiments in order to improve this branch of its service. For this purpose the board employed Prof. J. H. Alexander, of Baltimore, who made a report on the subject, which was published among the documents. The investigations of Professor Alexander related especially to the use of the locomotive steam-whistle as a fog-signal, and in his report he details the results of a series of experiments in regard to the nature and adjustment of the whistle, the quantity of steam necessary to actuate it, with suggestions as to its general economy and management. He found, what has since been fully shown, that the power of the sound depends upon the pressure of the steam in the boiler, and the pitch upon the distance between the circular orifice through which the steam issues, and the edge of the bell. He appears however to be under an erroneous impression that the sound is produced by the vibrations of the metal of the goblet or bell, while in fact this latter portion of the apparatus is a resounding cavity, which, as I have shown in subsequent experiments, may be constructed of wood as well as of brass, in order to produce the same effect. Mr. Alexander also mentions the effect of the wind in diminishing the penetrating power of sound when in an adverse direction, either directly or approximately. He also recommends the adoption of an automatic pump to supply the boilers with water, and also to open and shut the valves at the proper intervals for blowing the whistle. He states that the location of a sound can be determined more precisely in the case of loud, high sounds than in that of feebler or lower ones. On this point I am not prepared to concur with him in experiments of my own. In all cases however loud sounds are more desirable than feebler ones, in order that they may be heard at a greater distance above the noise of the surf and that of the wind as it passes through the spars and rigging of vessels.

The board however at this time were not prepared to adopt these suggestions, and an unsuccessful attempt to use a steam-boiler, rendered abortive by the incapacity of the keeper to give it proper attendance, discouraged for a time efforts in this line.

Previous to the investigations of Mr. Alexander, at the expense of the Light House Board, Mr. Daboll, of New London, had for several years been experimenting on his own account with reference to a fog-signal. His plan consisted in employing a reed trumpet, constructed after the manner of a clarionet, and sounded by means of air condensed in a reservoir, the condensation being produced by horse-power operating through suitable machinery. Although the sound of this was more penetrating than that of bells, still the expense and inconvenience of the maintenance of a horse, together with the cost of machinery, prevented its adoption. Mr. Daboll however after this presented to the board a modification of his invention, in which a hot-air engine of Ericsson's patent was substituted as the motive power, instead of the horse; and the writer ot this report, as chairman of the committee on experiments in behalf of the board, examined this invention and reported in favor of its adoption. The other members of the committee made an unfavorable report, on the ground that fog-signals were of little importance, since the mariner should know his place by the character of his soundings in all places where accurate surveys had been made, or should not venture near the coast until the fog was dissipated. The board however established Daboll trumpets at different stations, which have been in constant use up to the present time.

PART I.—INVESTIGATIONS FROM 1865 TO 1872.*

EXPERIMENTS NEAR NEW HAVEN, IN 1865.

The subject of sound, in connection with fog-signals, still continued to occupy the attention of the board, and a series of investigations was made in October, 1865, at the light-house near New Haven, under the direction of the writer of this report, in connection with Commodore, now Admiral, Powell, inspector, and Mr. Lederle, acting engineer of the third district.

The principal object was to compare the sound of bells, of steam-whistles, and other instruments, and the effect of reflectors, and also the operation of different hot-air engines. For this purpose the committee was furnished with two small sailing-vessels. As these were very imperfectly applicable, since they could not be moved without wind, the writer of the report devised an instrument denominated an "artificial ear," by which the relative penetrating power of different sounding bodies could be determined and expressed in numbers by the removal of the observer to a comparatively short distance from the point of origin of the sound. This instrument consisted of a conical horn, made of ordinary tinned sheet-iron, the axis of which was about 4 feet in length, the diameter of the larger end 9 inches, and tapering gradually to 1¾ of an inch at the smaller end. The axis of this horn was bent at the smaller end in a gentle curve, until the plane of the section of the smaller end was at right angles to the perpendicular section of the larger end, so that when the axis of the trumpet was held horizontally and the larger section vertically, then the section of the smaller end would be horizontal. Across the smaller end a thin membrane of gold-beater's skin was slightly stretched and secured by a thread. On this membrane fine sand was strewn. To protect the latter from disturbance by the wind, it was surrounded by a cylinder of glass, cut from a lamp-chimney, the upper end of which was covered with a plate of glass; and, in the improved condi-

* From the Report of the Light-House Board, for 1874.

tion of the instrument, with a magnifying lens, with which to observe more minutely the motions of the sand. To use this instrument in comparing the relative penetrating power of sound from different sources, as for example from two bells, the axis being held horizontal, the mouth was turned toward one of the bells, and the effect causing agitation of the sand, was noted. The instrument was then removed to a station a little further from the bell, and the effect again noted, the distance being increased, step by step, until no motion in the sand could be observed through the lens. This distance, being measured in feet or yards, gave the number indicating the penetrating power of the instrument under trial. The same experiment was immediately repeated, under the same conditions of temperature, air, wind, &c., with the other sounding apparatus, and the relative number of yards indicating the distance, taken as the penetrating powers of the two instruments. It should be observed, in the use of this instrument, that it is intended merely to concentrate the rays of sound, and not to act as a resounding cavity; since in that case the sound, in unison with the resounding note, would produce effect at a greater distance than one in discord.

The indications of this instrument were compared with the results obtained by the ear in the use of the two vessels, and in all cases were in exact accordance; and it was accordingly used in the following investigations, and has been found of great service in all subsequent experiments on the penetration of sound.

The only precaution in using it is that the membrane shall not be of such tension as to vibrate in unison with a single sound or its octaves; or, in other words, that the instrument must be so adjusted by varying the length of the axis or the tension of the membrane that it shall be in discordance with the sounds to be measured, and only act as a condenser of the sonorous waves.

The first experiments made were with regard to the influence of reflectors. For this purpose a concave wooden reflector had been prepared, consisting of the segment of a sphere of 16 feet radius, and covered with plaster, exposing a surface of 64 square feet. In the focus of this, by means of a temporary railway, a bell or whistle could be readily introduced or withdrawn. The center of the mouth of the bell was placed in the horizontal axis of the reflector. This arrangement being completed, the sound of the bell, with and without the reflector behind it, was alternately observed. Within the distance of about 500 yards the effect was evidently increased, as indicated by the motion of the sand on the membrane, but beyond this the difference was less and less perceptible, and at the limit of audibility the addition of the reflector appeared to us entirely imperceptible. This result was corroborated by subsequent experiments in which a whistle was heard nearly as well in the rear of a reflector as before it. It would appear from these results that while feeble sounds, at small distances, are reflected as rays of light are, waves of powerful sound spread laterally, and even when projected from the mouth of a trumpet, tend at a great distance to embrace the whole circle of the horizon.

Upon this and all the subsequent experiments, as it will appear, the principle of reflection as a means of re-enforcing sound is but slightly applicable to fog-signals. It is evident however that the effect will be somewhat increased by augmenting the size of the reflector, and by more completely inclosing the source of sound in a conical or pyramidal reflector.

Another series of experiments was made to ascertain whether the penetration of the sound was greater in the direction of the axis of the bells, or at right angles to the axis; or, in other words, whether the sound was louder in front of the mouth of a bell or of its rim. The result of this experiment was considered of importance, since, in one of the light-houses, a bell has been placed with the plane of its mouth at right angles to the horizon, instead of being placed, as usual, parallel to the same. The effect on the sound in these two positions was similar to that produced by the bell with a reflector, the noise being greater at a short distance with the mouth toward the observer than when the rim was in the plane of the ear. At a distance however, the difference between the two sounds was imperceptible. In practice therefore it is of very little importance whether the axis of the bell is perpendicular or parallel to the horizon.

The first fog-signal examined in this series of experiments was a double whistle, improperly called a steam-gong, designed principally for a fire-alarm and for signals for the commencement of working-hours in large manufacturing establishments. It consisted of two bells of the ordinary steam-whistle on the same hollow axis, mouth to mouth, with a flat, hollow cylinder between them, through the upper and lower surface of which the circular sheets of steam issue, the vibration of which produces the sound. In the instrument under examination, the upper bell was 20 inches in length of axis, and 12 inches in diameter, and the lower-whistle was of the same diameter, with a length of axis of 14 inches. The note of the shorter bell was a fifth above that of the longer. This arrangement gave a melodious sound, unlike that of the ordinary locomotive-whistle, and on that account had a peculiar merit. The sound was also very loud, and, according to testimony, had been heard under favorable circumstances more than twenty miles. It however required a large quantity of steam to give it its full effect, and the only means to obtain an approximate idea as to this quantity was that afforded by observing its action on a boiler of a woolen manufactory near Newport. It was here blown with a pressure of at least 75 pounds. From theoretical considerations however, it might be inferred that its maximum penetrating power would be not greater than that of a single whistle using the same amount of steam, and this theoretical inference was borne out by the subsequent experiments of General Duane. But from the strikingly distinctive character of its tone it has, in our opinion, an advantage over a single whistle expending an equal quantity of steam.

The fact that the vibration of the metal of the bell had no practical effect on the penetrating power of the sound was proved quite conclusively by winding tightly around each bell, over its whole length, a thick cord, which would effectually stop all vibration. The penetration of the sound produced under this condition was the same as that with the bells free. It is true, the latter produces a difference in the quality of the tone, such as that which is observed in a brass instrument and that of one of wood or ivory. The inventor was not aware that the sound produced was from the resonance of the air within the bell, and not from the metal of the bell itself, and had obtained a patent, not only for the invention of the double whistle, but also for the special compound of metal of which it was composed.

Another apparatus proposed to be used as a fog-signal was presented for examination by the Marine Signal Company, of Wallingford, Conn. It consisted of a curved tube of copper nearly in the form of the letter C, and was supported on an axis passing through the center of the figure. An ordinary bell-whistle was attached to each extremity of the tube, the instrument being placed in a vertical position and partially filled with water, then made to oscillate on its center of support. By this means the air was drawn in at one end and forced out through the whistle at the other. The motion being reversed the air was drawn in at the end through which it had just made its exit and forced out through the whistle at the other. By rocking the instrument, either by hand or by the motion of the vessel, a continued sound could be produced. The motive-power in the former case was muscular energy, and the experiments which were made at this time, as well as all that have been made subsequently, conclusively prove that the penetrating power of the sound for practical use as a fog-signal depends upon the intensity of the motive-energy employed. No instrument operated through levers and pumps by hand-power is sufficient for the purpose.

One of these instruments with two 4-inch whistles gave a sound, as indicated by the artificial ear, the power of which was about one-tenth of that of a steam-trumpet. It was supposed however that this instrument would be applicable for light-ships; and that if extended entirely across the vessel, and armed with whistles of large size, it would be operated by the rolling of the vessel, and thus serve to give warning in time of thick weather. But as it frequently happens that fog exists during a calm, this invention could not be relied upon to give warning in all cases of danger. Besides this, the ordinary roll of a ship is not sufficient to produce a hydrostatic pressure of more than five or six pounds to the square inch, which is insufficient to give an effective sound. It has however been proposed to increase the power by using quicksilver instead of water; but, besides the first cost of this material, and the constant loss by leakage and oxidation, the tendency to affect the health of the crew is an objection to the introduction of this modification of the apparatus into light-ships.

The other instruments which were subjected to trial were an ordinary steam-whistle and a Daboll trumpet. The bell of the whistle was 6 inches in diameter, 9 inches in height, and received the sheet of steam through an opening of one-thirtieth of an inch in width; was worked by a pressure of condensed air of from 20 to 35 pounds per square inch, and blown once in a minute for about five seconds. The air was condensed by a Roper engine of one-horse power. The penetrating power of the sound was increased by an increase in the pressure of the air, and also the pitch. The tone however of the instrument was lowered by increasing the distance between the orifice through which the circular sheet of air issued at the lower rim of the bell or resounding cavity. To prove conclusively that the bell performs the part of a mere resounding cavity, a wooden one, on a subsequent occasion, was substituted for that of metal without a change in the loudness or the pitch of the sound.

The penetrating power of the whistle was compared with a Daboll trumpet, actuated by an Ericsson engine of about the same power; the reservoir for the condensed air of each machine was furnished with a pressure-gauge, and by knowing the capacity of the condensing pumps and the number of strokes required to produce the pressure, the relative amount of power was determined. The result was that the penetrating power of the trumpet was nearly double that of the whistle, and that an equal effect was produced at the same distance by about one-fourth of the power expended in the case of the latter. It must be recollected however, that the whistle sends sonorous waves of equal intensity in every direction, while the greatest power of the trumpet is in the direction of its axis. This difference however is lessened on account of the spreading of the sound to which we have before alluded.* The whistle was blown, as we have said, with a pressure of from 20 to 35 pounds, while the trumpet was sounded with a pressure of from 12 to 15 pounds. In the case of the whistle, the pressure in the reservoir may be indefinitely increased with an increase in the penetrating power of the sound produced, while in the case of the trumpet a pressure greater than a given amount entirely stops the blast by preventing the recoil of the vibrating tongue; this being made of steel, in the larger instruments 2½ inches wide and 8 inches long, would receive a pressure of steam, at only 10 pounds to the square inch, of 200 pounds, tending to press it into the opening and to prevent its recoil, this circumstance limits, as it were, the power of a trumpet of given dimensions. It is however well fitted to operate with a hot-air engine, and is the least expensive in fuel of any of the instruments now employed. The whistle is the simpler and easier of management, although they both require arrangement of machinery in order that they may be operated automatically.

* It is worthy of note however that in the case of a sound having primarily an axial direction, the subsequent lateral diffusion must result in enfeebling the whole sphere of expanding sound-waves in a more rapid ratio than the square of the distance.

It is a matter of much importance to obtain a hot-air engine of sufficient power, and suitable for working fog-signals of all classes. This will be evident when we consider the difficulty in many cases of obtaining fresh water for producing steam, and the expense of the renewal of the boilers in the use of salt-water, as well as that of the loss of power in frequently blowing out the latter, in addition to the danger of the use of steam by unskillful attendants.

The merits of the two engines however under consideration could not be fully tested by the short trial to which they were subjected during these experiments. The principal objection to the Ericsson engine was the size of the fly-wheel and the weight of the several parts of the machine; the Roper engine was much more compact, and appeared to work with more facility, but from the greater heat imparted to the air the packing was liable to burn out and required to be frequently renewed. Although at first the impression of the committee was in favor of the Roper engine, yet in subsequent trials of actual practice it was found too difficult to be kept in order to be employed for light-house purposes, and its use has consequently been abandoned; another hot-air engine has been employed by the board, the invention of a Mr. Wilcox, which has also been discontinued for a similar reason. I was assured by the person last named, a very ingenious mechanician, that when the several patents for hot-air engines expired, a much more efficient instrument could be devised by combining the best features of each of those now in use.

For determining the relative penetrating power of these instruments, the use of two vessels had been obtained, with the idea of observing the sound simultaneously in opposite directions.

Unfortunately however the location which had been chosen for these experiments was of a very unfavorable character in regard to the employment of sailing-vessels and the use of the artificial ear. It was fully open to the ocean only in a southerly direction, navigation up the bay to the north being limited to three and a half miles, while on shore a sufficient unobstructed space could not be obtained for the proper use of the artificial ear. With these obstructions and the necessity of beating against the wind, thereby constantly altering the direction of the vessel, exact comparisons were not possible, yet the observations made were sufficiently definite to warrant certain conclusions from them as to the relative power of the various instruments submitted to examination.

The following is a synopsis of the observations on four different days. Before giving these however, it is necessary to observe that at each stroke of the piston of the hot-air engine a loud sound was produced by the blowing off of the hot air from the cylinder, after it has done its work. In the following statement of results the noise thus produced is called the exhaust. On the first day but one set of observations was made, the vessel's course being nearly in the line of the axis of the trumpet. The order of penetrating power was as follows: 1, trumpet; 2, exhaust; 3, bell; these instruments being heard respectively at $5\frac{1}{8}$, $3\frac{1}{2}$, and 2 miles. The whistle was not sounded.

The second day simultaneous observations were made from two vessels sailing nearly in opposite directions. The results of the observations made on the vessel sailing in a southerly direction were very irregular. The trumpet was heard at $3\frac{5}{8}$ miles and lost at $4\frac{3}{8}$ miles with the wind slightly in favor of the sound, and heard at $6\frac{1}{4}$ miles with the wind somewhat against the sound; it was heard even at $7\frac{5}{8}$ miles from the masthead, though inaudible from the deck. In all these cases the position of the vessel was nearly in line with the axis of the trumpet.

The whistle and exhaust were heard at $7\frac{1}{4}$ miles with a feeble opposing wind, and lost at $6\frac{1}{4}$ miles when the force of the wind became greater.

The order of penetration in this series of observations was: 1, trumpet and gong; 2, whistle; 3, exhaust.

In the case of the vessel sailing northward, its course being almost directly against the wind and in the rear of the trumpet, all the sounds were lost at less distances than in the case of the other vessel. The observations showed very clearly the effect of the wind, the bell at a certain distance being heard indistinctly with a strong opposing wind and more and more plainly as the wind died away. The trumpet was heard only as far as the whistle, the vessel being in the rear of it.

The third day observations were made from the two vessels, both however sailing to the south. From the vessel sailing at right angles to the direction of the wind the order of penetration was: 1, trumpet; 2, whistle; 3, exhaust; 4, bell.

In the case of the other vessel the opposing effect of the wind was greater, and the sounds were heard to a less distance; the order was: 1, trumpet; 2, whistle; 3, exhaust; 4, bell; 5, rocker.

On the fourth day two trips were made by the same vessel in the course of the day, one being northward and the other southward. In the first case the trumpet was lost at $3\frac{1}{8}$ miles, the vessel being nearly in its rear; in the second case, the wind being almost directly opposed to the sound, the large bell was heard at $1\frac{1}{8}$ miles, and lost at $\frac{7}{8}$ of a mile, probably due to increase of the force of the wind; the trumpet was was lost at $3\frac{1}{2}$ miles.

In all these observations, owing to the unfavorable conditions of the locality, and the direction of the wind, we were unable to obtain any satisfactory observations on sound moving with the wind. In all cases the results were obtained from sounds moving nearly against the wind, or at right angles to it. From the results of the whole it appears that the sound was heard farther with a light opposing wind than with a stronger one, and that it was heard farthest of all at right angles to the wind. From this latter fact, however, it should not be inferred that in this case sound could be heard farther at right angles to the wind than with the wind, but that in this direction the effect of the wind was neutralized. The results also exhibited, in a striking manner, the divergency of sound from the axis of the trumpet, the trumpet being heard in the line of its axis in front at 6 miles and behind at 3, the wind being nearly the same in both cases.

All the observations were repeated on land with the artificial ear as far as the unfavorable condition of the surface would permit. Although the limit, as to distance, at which the sand might be moved was not in most cases observed, yet the relative degree of agitation at a given distance established clearly which was the most powerful instrument, the result giving precisely the same order of penetration of the different instruments as determined by direct audition.

During this series of investigations an interesting fact was discovered; namely, a sound moving against the wind, inaudible to the ear on the deck of the schooner, was heard by ascending to the mast-head. This remarkable fact at first suggested the idea that sound was more readily conveyed by the upper current of air than the lower, and this appeared to be in accordance with the following statement of Captain Keeney, who is commander of one of the light-house vessels, and has been for a long time on the banks of Newfoundland in the occupation of fishing: "When the fishermen in the morning hear the sound of the surf to the leeward, or from a point toward which the wind is blowing, they take this as an infallible indication that in the course of from one to five hours the wind will change to the opposite direction from which it is blowing at the time." The same statement was made to me by the intelligent keeper of the fog-signal at Block Island. In these cases it would appear that the wind had already changed direction above, and was thus transmitting the sound in an opposite direction to that of the wind at the surface of the earth.

Another remarkable fact bearing on this same point is established by the observations of General Duane. At Cape Elizabeth, 9 miles southeasterly from the general's house, at Portland, is a fog-signal consisting of a whistle 10 inches in diameter; at Portland Head, about 4 miles from the same city, in nearly the same direction, is a Daboll trumpet. There can be no doubt, says the general, that those signals can be heard much better during a heavy northeast snow-storm than at any other time. "As the wind increases in force, the sound of the nearer instrument, the trumpet, diminishes, but the whistle becomes more distinct; but I have never known the wind to blow hard enough to prevent the sound of the latter from reaching this city." In this case, the sound comes to the city in nearly direct opposition to the course of the wind, and the explanation which suggested itself to me was that during the continuance of the storm, while the wind was blowing from the northeast at the surface, there was a current of equal or greater intensity blowing in an opposite direction above, by which the sound was carried in direct opposition to the direction of the surface current. The existence of such an upper current is in accordance with the hypothesis of the character of a northeast storm, which sometimes rages for several days at a given point on the coast without being felt more than a few miles in the interior, the air continuously flowing in below and going out above. Indeed, in such cases a break in the lower clouds reveals the fact of the existence above of a rapid current in the opposite direction.

The full significance, however, of this idea did not reveal itself to me until in searching the bibliography of sound I found an account of the hypothesis of Professor Stokes in the Proceedings of the British Association for 1856,* in which the effect of an upper current in deflecting the wave of sound so as to throw it down upon the ear of the auditor, or directing it upward far above his head, is fully explained. This subject will be referred to in the subsequent parts of the report, in the attempt to explain various abnormal phenomena of sound which have been observed during the series of investigations connected with the Light-House Board.

During these investigations an attempt was made to ascertain the velocity of the wind in an upper stratum as compared with that in the lower. The only important result however, was the fact that the velocity of the shadow of a cloud passing over the ground was much greater than that of the air at the surface, the velocity of the latter being determined approximately by running a given distance with such speed that a small flag was at rest along the side of its pole. While this velocity was not perhaps greater than six miles per hour, that of the shadow of the cloud was apparently equal to that of a horse at full speed.

During this and subsequent investigations, inquiries were made in regard to the effect of fog upon sound, it being a subject of considerable importance to ascertain whether waves of sound, like the rays of light, are absorbed or stifled by fog. On this point, however, observers disagree. At first sight, from the very striking analogy which exists in many respects between sound and light, the opinion largely prevails that sound is impeded by fog; although observers who have not been influenced by this analogy have, in many instances, adopted the opposite opinion, that sound is better heard during a fog than in clear weather. For instance, the Rev. Peter Ferguson, of Massachusetts, informs me that from his own observations, sound is conveyed farther in a fog than in a clear air. He founds this opinion on observations which he has made on the sound of locomotives of several railways in passing over bridges at a distance. Unfortunately, the question is a difficult one to settle, since the effect of the wind, in order to arrive at a true result, must be carefully eliminated. Captain Keeney, who has previously been mentioned, related the following occurrence, in the first part of which he was led to suppose that fog had a very marked influence in deadening sound, though in a subsequent part he came to an opposite conclusion: He was sailing during a dense fog, with a slight wind bear-

* Report of British Association, 1856; Abstracts, p. 22.

ing him toward a light-vessel, the locality of which he expected to find by means of the fog-signal. He kept on his course until he thought himself very near the ship, without hearing the stroke of the bell. He then anchored for the night, and found himself next morning within a short distance of the light-vessel, but still heard no sound, although he was assured when he got to it that the bell had been ringing all night. He then passed on in the same direction in which he had previously sailed, leaving the light-vessel behind, and constantly heard the bell for a distance of several miles, the density of the fog not perceptibly diminishing. In this case it is evident that the deadening of the sound was not due to the fog, but, as we shall hereafter see, in all probability to the combined action of the upper and the lower currents of air.

On returning to Washington the writer took advantage of the occurrence of a fog to make an experiment as to the penetration of the sound of a small bell rung by clock-work, the apparatus being the part of a moderator-lamp intended to give warning to the keepers when the supply of oil ceased. The result of the experiment was contrary to the supposition of absorption of the sound by the fog, but the change in the condition of the atmosphere as to temperature and the motion of the air, before the experiment could be repeated in clear weather, rendered the result not entirely satisfactory.

Experiments at Sandy Hook in 1867.

The next series of experiments was made from October 10 to October 18, 1867, under the direction of the writer of this report, in connection with General Poe, engineer-secretary of the Light-House Board, Commodore (now Admiral) Case, then inspector of the third light-house dis-district, and Mr. Lederle, acting engineer of the same district.

The principal object of these investigations was to compare different instruments, and to ascertain the improvements which had been made in them since the date of the last investigations, especially the examination of a new fog-signal called the siren, and the comparison of it with the Daboll trumpet, although other investigations were made relative to the general subject of sound in relation to fog-signals. The locality chosen was Sandy Hook, a narrow peninsula projecting northward, about five miles into the middle of the Lower Bay of New York, and almost at right angles to its coast, having a width of about half a mile. Near the northern point on the east shore a temporary building was erected for the shelter of the engines and other instruments.

The comparisons in regard to penetrating power were made by the use of the artificial ear, heretofore described, by carrying this off a measured distance until the sand ceased to move. This operation was much facilitated by previous surveys of members of the Engineer Corps, who had staked off a straight line parallel with the shore, and accurately divided it into equal distances of 100 feet.

On account of the character of the deep and loose sand, walking along this distance was exceedingly difficult, and, to obviate this, a carriage with broad wheels, drawn by two horses, was employed. An awning over this vehicle protected the observer from the sun, and enabled him, without fatigue and at his ease, to note the agitations of sand on the drum of the artificial ear, the mouth of which was directed from the rear of the carriage toward the sounding instrument.

For these and other facilities we were indebted to General Humphreys, Chief of the Engineer Bureau, who gave orders to the officer in charge of the military works at Sandy Hook to afford us every aid in his power in carrying on the investigation.

The instruments employed were—

1st. A first-class Daboll trumpet (the patent for which—since the death of Mr. Daboll, is owned by Mr. James A. Robinson,) operated by an Ericsson hot-air engine. It carried a steel reed 10 inches long, 2¾ inches wide, and ½ inch in thickness at the vibrating end, but increasing gradually to an inch at the larger extremity. This was attached to a large vertical trumpet curved at the upper end into a horizontal direction and furnished with an automatic arrangement for producing an oscillation of the instrument of about 60° in the arc of the horizon. Its entire length, including the curvature, was 17 feet. It was 3½ inches at the smaller end and had a flaring mouth 38 inches in diameter. The engine had a cylinder 32 inches in diameter, with an air-chamber of 4½ feet in diameter and 6 feet long, and was able to furnish continually a five-second blast every minute at a pressure of from 15 to 30 pounds.

2d. A siren, originally invented by Cagniard de Latour, and well known to the physicist as a means of comparing sounds and measuring the number of vibrations in different musical notes. Under the direction of the Light-House Board, Mr. Brown, of New York, had made a series of experiments on this instrument in reference to its adoption as a fog-signal, and these experiments have been eminently successful. The instrument as it now exists differs in two essential particulars from the original invention of Latour: 1st, it is connected with a trumpet in which it supplies the place of the reed in producing the agitation of the air necessary to the generation of the sound; and 2d, the revolving disk, which opens and shuts the orifices producing the blasts, is driven not by the blast itself impinging on oblique openings, as in the original instrument, but by a small engine connected with the feed-pump of the boiler.

The general character of the instrument may be understood from the following description: Suppose a drum of short axis, into one head of which is inserted a steam-pipe connected with a locomotive-boiler, while the other end has in it a triangular orifice, through which the steam is at brief intervals allowed to project itself. Immediately before this head, and in close contact with it, is a revolving disk, in which are eight orifices. By this arrangement, at every complete revolution of the disk, the orifice in the head of the drum is opened and shut eight times in succession, thus producing a rapid series of impulses of steam against the air into the smaller orifice of the trumpet placed immediately in front of the revolving disk. These impulses are of such intensity and rapidity as to produce a sound unrivalled in magnitude and penetrating power by that of any other instrument yet devised.

The siren was operated by an upright cylindrical tubular boiler, with a pressure of from 50 to 100 pounds on the square inch. For this form of boiler has been subsequently substituted an ordinary horizontal locomotive-boiler with a small engine attached for feeding it and for rotating the disk, the latter being effected by means of a band passing over pulleys of suitable relative dimensions.

3d. A steam-whistle 8 inches in diameter. Through some misunderstanding a series of whistles of different diameters was not furnished as was intended.

The first experiments to be noted were those in regard to the comparison of penetrating power of the siren and the whistle, the fitting up of the Daboll trumpet not having been completed. The principal object of this however was to test again the truthfulness of the indications of the artificial ear in comparison with those of the natural ear.

An experiment was made both by means of the artificial ear on land and by actually going off on the ocean in a steamer until the sounds became inaudible to the natural ear. By the latter method the two sounds ceased to be heard at the distances of six, and twelve and a half miles, respectively. The indications of the artifical ear gave a similar result, the distance at which the sand ceased to move in one case being double that of the other. In both cases the conditions of wind and weather were apparently the same. In the case of the steamer the distance was estimated by noting the interval of time between the flash of steam and the perception of the sound.

Comparison of the Daboll trumpet and the siren.—The pressure of the hot air in the reservoir of the hot-air engine of the trumpet was about 20 pounds, and that of the steam in the boiler of the siren about 75 pounds. These pressures are however not considered of importance in these experiments, since the object was not so much to determine the relative amount of motive power employed as the amount of penetrating power produced by these two instruments, each being one of the first of its class.

1. At distance 50 the trumpet produced a decided motion of the sand, while the siren gave a similar result at distance 58. The two observations being made within ten minutes of each other, it may be assumed that the condition of the wind was the same in the two cases, and hence the numbers above given may be taken as the relative penetrating power of the two instruments.

2. Another series of experiments was instituted to determine whether a high or a low note gave the greatest penetration. For this purpose the

siren was sounded with different velocities of rotation of the perforated disk, the pressure of steam remaining at 90 pounds per square inch. The effect upon the artificial ear in causing greater or less agitation of sand was taken as the indication of the penetrating power of the different tones. The number of revolutions of the disk in a given time was determined by a counting apparatus, consisting of a train of wheels and a series of dials showing tens, hundreds, and thousands of revolutions; this was temporarily attached to the projecting end of the spindle of the revolving disk by pushing the projecting axis of the instrument into a hole in the end of the spindle.

From the whole of this series of experiments it appeared that a revolution which gave 400 impulses in a second was the best with the siren when furnished with a trumpet. On reflection however it was concluded that this result might not be entirely due to the pitch, but in part to the perfect unison of that number of impulses of the siren with the natural tone of the trumpet. To obviate this complication, a series of experiments was next day made on the penetration of different pitches with the siren alone, the trumpet being removed. The result was as follows:

The siren was sounded at five different pitches, the artificial ear being at such a distance as to be near the limit of disturbance by the sound. In this condition the lowest pitch gave no motion of sand. A little higher, slight motion of sand. Still higher, considerable motion of sand; and with a higher pitch again, no motion of sand. The best result obtained was with a revolution which gave 360 impulses in a second.

3. An attempt was made to determine the most effective pitch or tone of the steam-whistle. It was started with what appeared to be the fundamental note of the bell, which gave slight motion of sand; a higher tone a better motion; still higher, sand briskly agitated; next, several tones lower, no motion; higher, no motion; still higher, no motion. The variation in the tone was made by altering the distance between the bell and the orifice through which the steam was ejected.

The result of this experiment indicated nothing of a definite character, other than that with a given pressure there is a maximum effect produced when the vibrations of the sheet of air issuing from the circular orifice are in unison with the natural vibrations from the cavity of the bell, a condition which can only be determined in any case by actual experiment. In practice, Mr. Brown was enabled to produce the best effect by regulating the velocity until the trumpet gave the greatest penetrating power, as indicated by an artificial ear of little sensibility, in order that it might be employed for determining the relative power while the observer was but a few yards from the machine.

These experiments have been made in an apartment of less than 80 feet in length, in which the sounding apparatus was placed at one end and the artificial ear at the other, substituting fine shot instead of sand.

The experiments with the siren however indicate the fact that neither the highest nor the lowest pitch of an instrument gives the greatest penetrating power, but one of a medium character.

Another element of importance in the construction of these instruments is the volume of sound. To illustrate this, it may be mentioned that a harpsichord-wire stretched between two strings of India rubber, when made to vibrate by means of a fiddle-bow, gives scarcely any appreciable sound. We attribute this to the want of quantity in the aerial wave; for if the same wire be stretched over a sounding-board having a wide area, the effect will be a comparatively loud sound, but of less duration, with a given impulse. It was therefore suggested that the width of the reed in the Daboll trumpet, the form and size of the holes in the disk of the siren, and the circumference of the vibrating sheet of air issuing from the circular orifice of the whistle, would affect the power of the sound. The only means of testing this suggestion is by using reeds of different widths, sirens with disks of different-shaped openings, and whistles of different diameters. In conformity with this view, Mr. Brown has made a series of empirical experiments with openings of different forms, which have greatly improved the operation of the siren, while Mr. Wilcox has experimented on several forms of reeds, of which the following is the result:

The best reed obtained was $2\frac{1}{4}$ inches wide, 8 inches long in the vibrating part, $\frac{5}{8}$ inch thick at the butt, and $\frac{1}{4}$ inch thick at the free end. This sounded at a pressure of from 20 to 30 pounds. The thinner reeds gave a sound at a less pressure, from 5 to 10 pounds, the thicker at from 20 to 30 pounds. A reed $8\frac{1}{2}$ inches long in the vibrating part, 1 inch thick at the butt, $\frac{3}{4}$ inch thick at the end, and 3 inches wide, did not begin to sound until a pressure of 80 pounds was reached, then gave a sound of a dull character. Another reed of the same width, $\frac{5}{8}$ inch thick at the butt, and $\frac{7}{16}$ inch at the end, and same length, gave a sound at 75 pounds pressure, but still dull and of little penetrating power. These reeds were evidently too heavy in proportion to their elasticity. These were made without the addition of a trumpet, and therefore to produce the best result when used with a trumpet, the latter must be increased or diminished in length until its natural vibrations are in harmony with those of the former, as will be seen hereafter. General Duane has also made experiments on whistles of different diameters, of which the result will be given.

Another consideration in regard to the same matter is that of the amplitude of the oscillations of the tongue or steel reed in its excursion in producing the sound; the time of oscillation remaining the same, that is, the pitch, the amplitude will depend upon the elasticity of the reed, the power to surmount which will again depend upon the pressure of steam in the boiler, and hence we might infer that an increase of pressure in the boiler with an increase of the elasticity of the reed, everything else being the same, would produce an increase in penetrating power. From the general analogy of mechanical effects produced by motive power, we may denote the effect upon the ear by the expression mv^2, in which m expresses the mass or quantity of air in motion, and v the velocity of the particles in vibration.

If this be the expression for the effect upon the ear, it is evident that in case of a very high note the amplitude of the vibration must be so small that the effect would approximate that of a continued pressure rather than that of distinct alternations of pressure, giving a vibrating motion to the drum of the ear.

4. Next, experiments were made to determine the penetrating power in the case of the siren under different pressures of steam in the boiler. The experiments commenced with a pressure of 100 pounds. The pressure at each blast was noted by two observers, and to compare these pressures with the indications of the sand, the time of the blasts was also noted.

The following are the results:

Pressure.	Relative distances at which the sand ceased to move.
100	61
90	59
80	58
70	57
60	57
50	56
40	55
30	53
20	51

From this series of experiments, it appears that a diminution of pressure is attended with a comparatively small diminution in the penetrating power of the siren.

In regard to this unexpected result of great practical importance, the following appears to be the explanation. It is a well-known principle in aerial mechanics that the velocity of the efflux of air from an orifice in a reservoir does not increase with an increase of condensation, when the spouting is into a vacuum. This is evident when we reflect that the weight of density of the air moving out is increased in proportion to the elasticity or pressure; that is, the increase in the propelling force is proportional to the increase in the weight to be moved, hence the velocity must remain the same.

In the foregoing experiments with high pressures large in proportion to the resistance of the air, the velocity of efflux should therefore be but little increased with the increase of pressure, and inasmuch as the velocity is the most important factor in the expression mv^2, which indicates the effect on the tympanum, the penetrating power of the sound should be in accordance with the above experimental results.

A similar result cannot be expected with the use of the whistle or the trumpet, since in the former the stiffness of the aerial reed depends upon its density, which will be in proportion to the pressure in the boiler, and in the case of the latter no sound can be produced on the one hand unless the pressure be sufficient to overcome the resistance of the reed, and on the other the sound must cease when the pressure is so great as to prevent the recoil of the reed.

5. An experiment was made to determine the effect of a small whistle inserted into the side of a trumpet near the small end. The whistle being sounded before and after it was placed in the trumpet, the result was as follows: The penetrating powers were in the ratio of 40: 51, while the tone was considerably modified. From this experiment it appears that a whistle may be used to actuate a trumpet or to exercise the functions of a reed. In order however to get the best results, it would be necessary that the trumpet and whistle should be in unison, but it may be doubted however whether an increase of effect, with a given amount of power, would result from using such an arrangement; it might nevertheless be of advantage in certain cases to direct the sound of a locomotive in a definite direction, and to use a smaller whistle, especially in cities, in which the locomotive passes through long streets; perhaps in this case the sound might be less disagreeable than that of the naked whistle, which sends its sound-waves laterally with as much force as in the direction of the motion of the engine.

6. General Poe called attention to the sound produced by the paddle-wheels of a steamer in the offing at a distance estimated at four and a half miles. The sound was quite distinct when the ears were brought near the surface of the beach.

In this connection he stated that he had heard the approach of a small steamer on the northern lakes when its hull was still below the horizon, and was even enabled to designate the particular vessel from among others by the peculiarity of the sound.

The sound in the case of the steamer is made at the surface of the water, and it might be worth the trouble to try experiments as to the transmission of sound under this condition, and the collection of it by means of ear-trumpets, the mouths of which are near the water, the sound being conveyed through tubes to the ears of the pilot. In order however to determine in this case the direction of the source of sound, two trumpets would be necessary, one connected with each ear, since we judge of the direction of a sound by its simultaneous effects on the two auditory nerves. This suggestion, as well as many others which have occurred in the course of these researches, is worthy of special investigation.

7. A series of experiments was made to compare trumpets of different materials and forms having the same length and transverse areas, all blown at a pressure of 9½ pounds.

The following table gives the results:

No.	Material of trumpet.	Cross-section.	Relative distances at which the sand ceased to move.
1	Wood.	Square.	13
2	Brass.	Circular.	23
3	Cast iron.	Circular.	24
4	Wood.	Circular.	30

From these experiments it would appear that the material or elasticity of the trumpet had little or no effect on the penetrating power of the sound, although the shape appeared to have some effect, the pyrimidal trumpet, or one with square cross-section (No. 1), giving a less result than the conical ones of the same sectional area. A comparison was made between a long straight trumpet and one of the same length curved at its upper end, which gave the same penetrating power with the same pressure. It is probable that a thin metallic trumpet would give greater lateral divergency to the sound, and also a slightly different tone.

8. The effect of a hopper-formed reflector was next tried with the whistle, the axis of which was about 5 feet in length, the mouth 6 feet square, and the small end about 18 inches. When the whistle was sounded at the small end of this reflector, the distance at which the sand ceased to move was 51; the sound of the same whistle without the reflector ceased to move the sand at 40. The ratio of these distances would have been less with a more sensitive instrument at a greater distance on account of the divergency of the rays.

9. In order to determine the diminution of sound by departing from the axis of the trumpet, a series of experiments was made with a rotating trumpet, the axis of which was at first directed along the graduated line of observation, and subsequently deflected from that line a given number of degrees. The following were the results:

Direction of the trumpet.	Relative distance at which sand moved.
Along the line	26
Deflected 30°	23
Deflected 60°	21
Deflected 90°	18
Deflected 120°	13

These results illustrate very strikingly the tendency of sound to spread on either side of the axis of the trumpet; had the experiments been made with a more sensitive instrument, and at a greater distance, the effect would have shown a much greater divergency. It should be observed however that the mouth of the trumpet in this case was 36 inches, which is unusually large.

From the experiments made near New Haven, and also from those at this station, it appears that the actual amount of power to produce sound of a given penetration is absolutely less with a reed trumpet than with a locomotive whistle. This fact probably finds its explanation in the circumstance that in each of these instruments the loudness of the sound is due to the vibration of the air in the interior of the trumpet and in the bell of the whistle, each of these being a resounding cavity; and furthermore that in these cavities the air is put in a state of sustained vibration by the undulations of a tongue, in the one case of metal, in the other of air; and furthermore it requires much more steam to set the air in motion by the tongue of air than by the solid tongue of steel, the former requiring a considerable portion of the motive power to give the current of which it consists the proper degree of stiffness, if I may use the word, to produce the necessary rapidity of oscillation. But whatever may be said in regard to this supposition, it is evident, in case reliable hot-air engines cannot be obtained, that the Daboll trumpet may be operated by a steam-engine, although at an increased cost of maintenance, but this increase we think will still not be in proportion to the sound obtained in comparison with the whistle.

Another question which naturally arises, but which has not yet been definitely settled by experment, is whether both the siren and the whistle would not, equally with the trumpet, give more efficient results when worked by condensed air than by steam.

From hypothetical considerations this would appear to be the case, since the intensity of sound depends upon the density of the medium in which it is produced; and as the steam is considerably lighter than air, and as the cavities of all of these instruments are largely filled with steam, the intensity of sound would, on this account, seem to be less than if filled with air.

At the conclusion of the experiments at Sandy Hook, the siren was adopted as a fog-signal, in addition to the reed-trumpet and the locomotive-whistle, to be applied to the more important stations, while large bells were retained for points at which fog-signals were required to be heard at but comparatively small distances. These instruments of the first class being adopted, it became of importance to determine, in actual practice, the cost of maintenance, the best method of working them, and any other facts which might have a bearing on their use.

But as investigations of this kind would require much time and peculiar advantages as to location and mechanical appliances, this matter was referred to General Duane, the engineer in charge of the 1st and 2d light-house districts, who had peculiar facilities near his residence, at Portland, Me., in the way of workshops and other conveniences, and who, from his established reputation for ingenuity and practical skill in mechanism, was well qualified for the work. The assignment of this duty to General Duane by the Light-House Board was made during my absence in Europe, in 1870, and as my vacation in 1871 was devoted to light-house duty in California, I had no opportunity of conferring with him on the subject until after his experiments were completed. His results are therefore entirely independent of those obtained under my direction, and I give them herewith in his own words, with such comments as they may suggest and as are necessary to a proper elucidation of the subject.

EXPERIMENTS AT PORTLAND, ME. 1871, BY GENERAL DUANE.

The apparatus employed consisted of the first-class siren, first-class Daboll trumpet and steam-whistles of various sizes.

The points to be decided were:

1st. The relative power of these machines; *i. e.*, the distances at which they could be heard under various conditions of the atmosphere.

2d. The amount of fuel and water consumed by each.

3d. The attention and skill required in operating them.

4th. Their endurance.

5th. Whether they are sufficiently simple in construction to permit of their being managed and kept in running order by the class of men usually appointed light-house keepers.

In conducting these experiments the following method was pursued:

The signals were sounded at alternate minutes, and their sound compared at distances of two, three, and four miles, and from different directions. On every occasion the quantity of fuel and water consumed per hour by each was carefully noted, and the condition of each machine examined, both before and after the trial, to ascertain whether any of its parts had sustained injury.

Before giving the results of these experiments some facts should be stated, which will explain the difficulty of determining the power of a fog-signal.

There are six steam fog-whistles on the coast of Maine; these have been frequently heard at a distance of twenty miles, and as frequently cannot be heard at the distance of two miles, and this with no perceptible difference in the state of the atmosphere.

The signal is often heard at a great distance in one direction, while in another it will be scarcely audible at the distance of a mile. This is not the effect of wind, as the signal is frequently heard much farther against the wind than with it. For example, the whistle on Cape Elizabeth can always be distinctly heard in Portland, a distance of nine miles, during a heavy northeast snow-storm, the wind blowing a gale directly from Portland toward the whistle.

[In this sentence, General Duane certainly does not intend to convey the idea that a signal is frequently heard "at a much greater distance against the wind than with it," since this assertion would be at variance with the general experience of mankind; but the word "frequently" applies to the whistle on Cape Elizabeth, which has been already mentioned as a remarkably exceptional case, in which the sound is heard best against the wind during a northeast snow-storm.]

The most perplexing difficulty, however, arises from the fact that the signal often appears to be surrounded by a belt, varying in radius from one to one and a half miles, from which the sound appears to be entirely absent. Thus, in moving directly from a station, the sound is audible for the distance of a mile, is then lost for about the same distance, after which it is again distinctly heard for a long time. This action is common to all ear-signals, and has been at times observed at all the stations, at one of which the signal is situated on a bare rock twenty miles from the main-land, with no surrounding objects to affect the sound.

All attempts to re-enforce the sound by means of reflectors have hitherto been unsuccessful. Upon a large scale, sound does not appear, on striking a surface, to be reflected after the manner of light and heat, but to roll along it like a cloud of smoke.

[This statement is in a measure in accordance with results which I have previously found in connection with investigations at the light-house near New Haven, in which the conclusion was arrived at, that although rays of feeble sounds, and for a short distance, observe the law that the angle of reflection is equal to the angle of incidence after the manner of light, yet powerful sounds tend to diverge laterally to such a degree as to render reflectors of comparatively little use.]

In view of these circumstances, it will be obvious that it was extremely difficult to determine the extent of the power of the various signals under examination.

It should be remembered that while the sound from the whistle is equally distributed in all directions,* that from the two other signals, both of which are provided with trumpets, is not so distributed.

[The difference is apparent near by, but, as we have seen before, on account of the tendency of sound to spread it is imperceptible at a distance.]

In the siren the sound is most distinct in the axis of the trumpet.

In the Daboll trumpet it is usually strongest in a plane perpendicular to this axis.

[This is at variance directly with any observation I have myself made.]

Relative power.—From the average of a great number of experiments the following result was obtained:

The power of the first-class siren, 12″ whistle, and first-class Daboll trumpet, may be expressed by the numbers 9, 7, 4.

The extreme limit of sound of the siren was not ascertained. That of the 12″ whistle is about twenty miles, and of the trumpet twelve.

Consumption of fuel and water.—The siren, when working with a pressure of 72 pounds of steam, consumes about 180 pounds of coal and 126 gallons of water per hour.

The 12″ whistle, with 55 pounds pressure of steam, consumes 60 pounds of coal and 40 gallons of water per hour.

The Daboll trumpet, with 10 pounds pressure of air in the tank, consumes about 20 pounds of coal per hour.

The relative expenditure of fuel would be: siren, 9; whistle, 3; trumpet, 1.

The siren.—Of the three machines this is the most complicated. It uses steam at a high pressure, and some of its parts move with very great velocity, the siren spindle making from 1,800 to 2,400 revolutions per minute. The boiler must be driven to its full capacity in order to furnish sufficient steam. A large quantity of steam is, at intervals, suddenly drawn from the boiler, causing a tendency to foam, and to eject a considerable amount of water through the trumpet.

The constant attention of the keeper is required to regulate the fire, the supply of water to the boiler, of oil to the journals, &c.

In general terms, it may be stated that the siren requires more skill and attention in its management than either of the other signals.

The Daboll trumpet.—As the caloric engine, which has been hitherto employed to operate this signal, requires little fuel, no water, and is perfectly safe as regards danger from explosion, it would, at the first glance, appear to be the most suitable power that could be applied to fog-signals, and was accordingly at first exclusively adopted for this purpose. It was however found to be so liable to accident and so difficult to repair that of late years it has been almost entirely rejected. In the steam-boiler the furnace is surrounded by water, and it is impossible, under ordinary circumstances, to heat the metal much above the temperature of the water. The furnace of the caloric engine is surrounded by air, and is therefore liable to be burned out if the fire is not properly regulated.

The working-piston is packed with leather, and as it moves horizontally, with its whole weight resting on the lower side of the cylinder, the packing at its lower edge is soon worn out.

If the engine is allowed to stop with the piston at the furnace-end of the cylinder,

* The sound of the whistle is equally distributed horizontally. It is, however, much stronger in the plane containing the lower edge of the bell than on either side of this plane. Thus, if the whistle is standing upright, in the ordinary position, its sound is more distinct in a horizontal plane passing through the whistle than above or below it.

the leather is destroyed by the heat. The repacking of a piston is a difficult and expensive operation, requiring more skill than can be expected among the class of men from whom light-house keepers are appointed.

Another accident to which these engines are subject arises from a sudden check in the velocity of the piston, caused either by the jamming of the leather packing or the introduction of dirt into the open end of the cylinder, in which case the momentum of the heavy, eccentrically-loaded fly-wheel is almost sure to break the main rocker-shaft.

The expense of repairs is considerably increased by the fact that these engines are not now in general use, and when important repairs are required it is usually necessary to send to the manufacturer.

This signal requires much attention. The fires must be carefully regulated to avoid burning out the furnace, the journals thoroughly oiled, and the cylinders well supplied with tallow.

The steam-whistle.—This machine requiring much less steam than the siren in proportion to the size of its boiler, there is not the same necessity for forcing the fire; the pressure of steam required is less, and the point from which it is drawn much higher above the water-level in the boiler, and there is consequently no tendency to foam.

The machinery is simple; the piston pressure very light, producing but little strain on the different parts of the engine, which is therefore not liable to get out of order and requires no more attention than a common stationary engine.

One marked advantage possessed by this signal is that should the engine become disabled, the whistle may still be sounded by working the valve by hand. This is not the case with the two others, where an accident to any part of the machinery renders the signal for the time useless.

It will thus be seen that the siren is the most expensive of the fog-signals as regards maintenance, and that it is adapted only to such stations as are abundantly supplied with water and situated in the vicinity of machine-shops where the necessary repairs can be promptly made.

On the other hand, as it is the most powerful signal, there are certain stations where it should have the preference; as, for example, Sandy Hook, which from its importance demands the best signal that can be procured, regardless of cost. Such stations should be provided with duplicate apparatus, well supplied with spare parts, to guard against any possibility of accident.

There should be a keeper whose sole business must be to attend the signal, and who should have sufficient mechanical skill to make the ordinary repairs. He should moreover be a licensed engineer.

There will also be required an assistant, who may be one of the light-keepers, to relieve him during the continuance of foggy weather.

The steam-whistle is the simplest in construction, most easily managed and kept in repair, and requires the least attention of all the fog-signals. It is sufficiently powerful for most localities, while its consumption of fuel and water is moderate.

It has been found on this coast that a sufficient quantity of rain-water can be collected to supply the 12″ whistle at nearly every station. This has been the case for the last two years at Martinicus.

The Daboll trumpet, operated by a caloric engine, should only be employed in exceptional cases, such as at stations where no water can be procured, and where, from the proximity of other signals, it may be necessary to vary the nature of the sound.

The trumpet however may undoubtedly be very much improved by employing steam power for condensing the air. The amount of work required, which is that of compressing 70 cubic feet of air to an average pressure of 8 pounds per inch, would be less than two-horse power. For this purpose the expenditure of fuel and water would be moderate; indeed, the exhaust steam could be condensed and returned to the cistern, should the supply of water be limited.

The siren also is susceptible of improvement, especially as regards simplification.

[In the foregoing remarks we think the general has expressed a somewhat undue partiality for the whistle, and somewhat overestimated the defects of the other instruments. The trumpets, with Ericsson engine, have not been abandoned, except partially in the two districts under the direction of General Duane, to which he probably intended to confine his statement. They are still in use in the third district, where they are preferred by General Woodruff, who finds no difficulty in keeping them in repair, having employed a skilled machinist who has made these instruments his special study, and who, visiting them from time to time, makes repairs and supplies new parts.]

The intermittent action of fog-signals makes it necessary to employ a peculiar form of boiler. The steam used is at a high pressure, and drawn off at intervals; consequently there is a tendency to foam and throw out water with the steam. To obviate this difficulty the form of boiler found by experience to be best adapted to this service is a horizontal tubular boiler (locomotive), with rather more than one-half of the interior space allowed for steam-room. The steam-dome is very large, and is surmounted by a steam pipe 12″ in diameter. Both the dome and pipe were formerly made much smaller, but were gradually enlarged as long as any difficulty with regard to foaming was noticed. The steam is drawn off at a point 10″ above the water-level in the boiler. The main points to be observed are to have plenty of steam-room, and to draw the steam from a point high above the water-level. It will be readily perceived that a vertical tubular boiler is entirely unsuited to this work.

It is essential, both as regards economy of fuel and the efficient working of the signal, that the boiler, including the dome and stand-pipe, should be well covered with some good non-conductor of heat. A material, called salamander felting, manufactured in Troy, N. Y., was used on the fog-whistle boiler at House Island during the winter of 1870. There resulted a saving of more than 20 per cent. of fuel over that consumed in the same boiler when uncovered. Where this material cannot be procured, a thick layer of hair felting, covered with canvas, will be found to answer a good purpose.

Various expedients have been proposed with the view of keeping the water in the boilers hot when the signals are not in operation, that the signal may always be ready to sound at a very short notice, and that the water in the boiler and pipes may be prevented from freezing in extremely cold weather. One of these contrivances is "Sutton's circulating water-heater." It consists essentially of a small, vertical, tubular boiler, entirely filled with water, and connected with the boiler or tank which contains the water to be heated, by two pipes on different levels. As soon as the water in the heater is warmed, a circulation commences, the hot water flowing through the upper pipe into the boiler, and the cold through the lower pipe from the boiler to the heater. As the furnace in the heater is very small but little fuel is consumed, and nearly the entire heat produced by the combustion is utilized.

The apparatus has been extensively employed in heating the water in tanks designed for filling the steam fire-engine boilers, when the alarm of fire is first given, and appears admirably adapted to this purpose. If used in connection with a steam-boiler, it should be disconnected before steam is raised in the latter, as, from its construction, it is not calculated to withstand any considerable pressure.

An arrangement, similar in principle, has been used in the first light-house district, consisting of a small cylinder coal-stove, of the ordinary pattern, around the interior of which, and above the grate, is introduced a single coil of ¾″ pipe. This coil is connected with the boiler by two pipes, one entering near the bottom, the other about 2 feet higher. It has been found that in consequence of the rapid circulation of the water through this coil, and the great capacity of water for heat, that nearly all the heat from the fire in the stove is transferred to the water in the boiler. This arrangement possesses the advantage of the ¾″ pipe, being strong enough to stand any pressure that can be used in the boiler, rendering it unnecessary to disconnect it at any time.

Experience has, however, proved that none of these contrivances are essential. It is seldom that an attentive keeper cannot foresee the approach of fog or snow in time to have the apparatus in operation as soon as required, even when obliged to start his fire with cold water in the boiler.

Keepers should be directed to watch the state of the weather carefully, and to light their fires at the first indication of fog or snow-storm. As soon as the water in the boiler is near the boiling point, should the necessity for sounding the signal have not yet arisen, the fire may be banked, and in this state the water may be kept hot for any length of time at a moderate expenditure of fuel. With proper care, no more fuel is required to keep the water at the requisite temperature by means of a banked fire than by any other method, and it is a matter of great importance to avoid complicating fog-signal apparatus by unnecessary appendages.

The same plan should be adopted in extremely cold weather to prevent the water in the boiler from freezing. There should be a small air-cock in the draught-pipe near its junction with the feed pump, and in cold weather this should be opened when the pump is not in use, in order to allow the pipe to empty itself.

When the draught-pipe cannot be protected from the cold, and the well is at a considerable distance from the engine, the following expedient has been employed with success: The pipe is inclosed in an India-rubber hose of about double its diameter, and from time to time steam is forced through the space between the hose and draught-pipe by means of a small pipe from the boiler.

Although the laws governing the reflection of light and heat are undoubtedly, in a great measure, applicable to sound, there are yet so many disturbing influences, such as inflection, refraction, caused by the varying density of the atmosphere, &c., interfering with the reflection of the latter, that but little use can be made of this property in directing and condensing the waves of sound issuing from a fog-signal. This fact may be illustrated by an account of some experiments made during the last year.

A whistle being sounded in the focus of a large parabolic reflector, it was very perceptible to an observer in the immediate vicinity that the sound was louder in the front than in the rear of the reflector. As the distance of the observer from the whistle was increased this disparity rapidly diminished, and at the distance of a few hundred yards entirely disappeared. The *beam* of sound had been dissipated and the *shadow* had vanished. The effect of a horizontal sounding-board 10 feet square, suspended over the whistle to prevent the escape of sound in a vertical direction, was inappreciable at the distance of a quarter of a mile.

The employment of a trumpet with the whistle was rather more successful. The trumpet was constructed of wood, in the form of a square pyramid; the lower base being 10′ by 10′, the upper base 2′ by 2′, and the height 20′. The axis was horizontal and the whistle placed at the smaller end. By this arrangement the increased power of the sound could be perceived at the distance of a mile, the action being similar to that of a speaking-trumpet.

It is probable that some modification of this form of whistle may be advantageously employed in certain localities, but there is however a disadvantage attending the use of a trumpet with fog-signals.

The sound from a trumpet not being uniformly distributed, it is difficult to estimate the distance of the signal, or, as the pilots term it, "to locate the sound." This has been observed in the siren and Daboll trumpet. The sound from these signals being stronger on one course than any other, may be distinctly heard from a vessel when crossing the axis of the beam of sound, but as its distance from this line increases, the sound appears fainter and more remote, although the vessel may be approaching the signal.

From an attentive observation, during three years, of the fog-signals on this coast, and from the reports received from captains and pilots of coasting vessels, I am convinced that in some conditions of the atmosphere the most powerful signals will be at times unreliable.

Now it frequently occurs that a signal, which under ordinary circumstances would be audible at the distance of fifteen miles, cannot be heard from a vessel at the distance of a single mile. This is probably due to the reflection mentioned by Humboldt.

The temperature of the air over the land where the fog-signal is located, being very different from that over the sea, the sound, in passing from the former to the latter, undergoes reflection at their surface of contact. The correctness of this view is rendered more probable by the fact that when the sound is thus impeded in the direction of the sea, it has been observed to be much stronger inland.

When a vessel approaches a signal in a fog, a difficulty is sometimes experienced in determining the position of the signal by the direction from which the sound appears to proceed, the apparent and true direction being entirely different. This is undoubtedly due to the refraction of sound passing through media of different density.

Experiments and observation lead to the conclusion that these anomalies in the penetration and direction of sound from fog-signals are to be attributed mainly to the want of uniformity in the surrounding atmosphere, and that snow, rain, fog, and the force and direction of the wind, have much less influence than has generally been supposed.

[In the foregoing I differ entirely in opinion from General Duane as to the cause of extinction of powerful sounds being due to the unequal density of the atmosphere. The velocity of sound is not at all affected by barometric pressure, but if the difference in pressure is caused by a difference in heat, or by the expansive power of vapor mingled with the air, a slight degree of obstruction of sounds may be observed. But this effect we think is entirely too minute to produce the results noted by General Duane, while we shall find in the action of the currents of wind above and below, a true and sufficient cause.]

The experimental whistles were of the following dimensions, viz: 2½″, 3″, 4″, 5″, 6″, 10″, 12″, and 18″ in diameter. Those of 2½″, 3″, 5″, and 10″ were fitted, instead of the ordinary bell, with long cylinders, provided with movable pistons, so that the effective length of the bell could be altered at pleasure. The pitch of the blast was found to vary with the length of the bell, and the power of the whistle with its diameter. The ratio of the power to the diameter was not accurately obtained, but it is probable that the extreme range of sound of a whistle is proportional to the square root of its diameter.

[This result, that the pitch varies with the length of the bell, is in conformity with well-established principles of resounding cavities; and that the power should increase with the extent of the aerial reed, the vibrations of which give motion to the resounding air within the cavity, is also, as we have seen, in accordance with hypothetical considerations; but as the density of this stream of steam, and consequently the rapidity of its vibrations, depends upon the pressure of the steam in the boiler, a perfect whistle should have the capability of changing its dimensions, not only in relation to the width of its throat, but also in regard to the pressure of the steam in the reservoir.]

The pitch giving the greatest range appears to be at the middle of the scale of sound. It is certain that a good result cannot be obtained from either a very shrill or a bass note. This remark is applicable to all varieties of signal.

The 10″ and 12″ whistles are recommended for ordinary use. The 18″ whistle is more powerful, but the increase of power bears too small a proportion to that of the expenditure of fuel to render its employment generally advisable. The best results were obtained by giving the whistle the following proportions: The diameter of the bell equaling two-thirds of its length, and the set of the bell, *i. e.*, the vertical distance of the lower edge above the cup, the one-third to one-fourth of the diameter for a pressure of 50 to 60 pounds of steam

A bell, whether operated by hand or by machinery, cannot be considered an efficient fog-signal on the sea-coast. In calm weather it cannot be heard half the time at a greater distance than one mile, while in rough weather the noise of the surf will drown its sound to seaward altogether.

On approaching a station I have frequently seen the bell rung violently by the keeper, without being able to hear the sound until I had landed.

Nevertheless, all important stations should be provided with bells, as there are occasions when they may serve a useful purpose, but it should be well understood by mariners that they must not expect always to hear the bells as a matter of course.

Bells should not be omitted at stations furnished with steam fog-signals, especially when the latter are not in duplicate, and mariners should be warned that the bell will be sounded when the regular signal is disabled.

It has been observed that a bell rung by hand can be heard further than when sounded by machinery, and many of the steamboat companies on this coast pay the keepers of bells rung by clock-work to ring them by hand when the boats of their line are expected to pass.

[We think the difference in the effect of ringing of bells by hand or by machinery is so slight as to be inappreciable except at a short distance. It is true, as I have before observed, that the sound is louder when the mouth of the bell is directed toward the hearer than when the edge is so directed, but on account of the spreading of this sound the effect is lost in a small distance, and indeed in one light-house the bell is permanently placed with the axis of its mouth directed horizontally, and in this position, if the bell were struck interiorly with a hammer, which would give it a larger vibration than when struck exteriorly, I doubt whether any difference would be observed between the two methods of ringing; and if any existed it would probably be in favor of the fixed bell rung by machinery.]

On rivers, narrow channels, and lakes, where the difficulty from the noise of the surf does not exist, this species of signal may be used to advantage, as its maintenance requires but a small expenditure of either money or labor, and by a proper arrangement of the machinery the intervals between the strokes of the bell may be so regulated as to avoid the danger of confounding the signals, however near together.

Although a bell may be heard better when sounded by hand than by clock-work, yet in thoroughfares where the signal must be kept in constant operation during the entire continuance of a fog, it would be impracticable to make use of the former method, and recourse must be had to machinery.

In arranging the signal the bell and machinery must be placed as low as possible, as the sound is heard much more plainly on the water when the bell is near its surface, and also as the machinery, when thus situated, is steadier and more readily accessible.

Particulars as to the siren.—The boiler of a second-class apparatus is 12 feet long, 42 inches in diameter, and has 300 feet heating-surface. The dome is 2 feet in diameter and 3 feet high.

The cylinder of the engine is 4 inches in diameter and 6 inches stroke. The prolongation of the piston-rod forms the plunger of the feed-pump. The main shaft carries three pulleys, the larger driving the siren-spindle; the second, the worm and screw gear; and the third, the governor.

In the worm-gear the wheel makes two revolutions per minute, and is provided with a cam, which, acting on a lever, opens the valve, admitting steam through the siren-disks. The cam has such a length as to hold the valve open for about seven seconds. A counter-weight closes the valve as soon as the lever is released by the cam.

The siren itself consists of a cylindrical steam-chest, closed at one end by a perforated brass plate. The perforations are twelve in number, equidistant from each other, and arranged on the circumference of a circle, whose center is in the axis of the cylinder. The other end is closed by a cast-iron head. The heads are connected by a brass pipe, through which the spindle passes.

The perforated head is covered on the exterior by a brass disk, attached to the spindle, having twelve rectangular notches corresponding to the apertures on the former, and so arranged that by its revolution these apertures are simultaneously opened and closed. The spindle is driven by a belt from the large pulley on the main shaft. This shaft makes 180 revolutions per minute; the spindle, 1,620; and as there are 12 apertures in the disks, from each there will issue jets of steam at the rate of 19,440 per minute. The sound produced by these impulses may be rendered more or less acute by increasing or diminishing the velocity of revolution.

The valve and valve-seat are disks similar to those already described, having however four openings instead of twelve. The valve revolves on the brass tube inclosing the siren-spindle, and is worked by a bevel gear. The trumpet is of cast-iron.

The Daboll trumpet.—The apparatus used in the foregoing experiments is a second-class trumpet, operated by an Ericsson caloric-engine. The air-pump is single-acting. Its cylinder is 12″ in diameter by 12″ stroke. The engine makes forty strokes per minute. There is a screw-thread raised on the main shaft, which, acting on a wheel, drives a bevel gear, giving motion to a cam-wheel. The latter makes one revolution in two minutes, and is furnished with three equidistant cams. These cams, pressing on the valve-lever, throw the valve open once in forty seconds, admitting the compressed air through the reed-chest into the trumpet.

The quantity of air forced into the tank should be in excess of that needed for the trumpet, the surplus being allowed to escape through a delicate safety-valve. This is necessary to provide against a deficiency in case of leakage, and also to allow the pressure of air to be regulated to accommodate the reed. Each reed requiring a different pressure, it is necessary to alter the pressure of the valve-spring whenever a reed is changed.

The first-class trumpet differs only in size from that described.

The caloric-engine for the first class has a 30″ cylinder. The air-pump is 16½″ by 15″ stroke.

The steam-whistle.—The boiler of this machine is that of the siren. On the forward part of the boiler the bed-plate of a small engine is secured by two cast-iron brackets. The cylinder of this engine is 4″ by 9″. The fly-wheel shaft carries an eccentric, which, acting through a rod and pawl on a ratchet-wheel, gives the required motion to the cam-wheel shaft.

The cam-wheel, which makes one revolution per minute, is provided with one or more cams, depending on the number of blasts to be given in a minute; the length of the blast being regulated by that of the cams.

The valve for admitting the steam into the whistle is a balance-valve, the diameters of the two disks being respectively 3¼″ and 2¾″, which difference is sufficient to cause the pressure of steam to close the valve tight without requiring too great a force to open it. The valve is worked by a stem attached to the rocker-shaft at the lower part of the steam-pipe. This shaft passes through a stuffing-box in the steam-pipe, and is provided with a collar which the pressure of the steam forces against the interior boss on the pipe, thus making the joint steam-tight. The exterior arm on this rocker-shaft, as well as that on the engine, is perforated in such a manner as to allow the throw of the valve to be adjusted.

In the comments we have made on the report of General Duane, the intention was not in the least to disparage the value of his results, which can scarcely be too highly appreciated; but inasmuch as the true explanation of the phenomena he has observed has an important bearing on the location of fog-signals and on their general application as aids to navigation, and are as well of great interest to the physicist, who values every addition to theoretical as well as practical knowledge, we have not only thought the remarks we have offered necessary, but also that special investigations should be made to ascertain more definitely the conditions under which the abnormal phenomena the general has described occur, and to assign, if possible, a more definite and efficient cause than those to which he has attributed them.

We have, therefore, given much thought to the subject, and since the date of General Duane's report, have embraced every opportunity which occurred for making observations in regard to them. The first step we made toward obtaining a clew to the explanation of the phenomena in question resulted from observations at New Haven, namely: 1st, the tendency of sound to spread laterally into its shadow; 2d, the fact that a sound is frequently borne in an opposite direction to the wind at the surface by an upper current; and 3d, that a sound moving against a wind is heard better at a higher elevation. The first point to consider is in what manner the wind affects sound. That it is in some way connected with the distance to which sound can be heard is incontestably settled by general observation. At first sight, the explanation of this might seem to be very simple, namely, that the sound is borne on in the one direction and retarded in the other by the motion of the wind. But this explanation, satisfactory as it might appear, cannot be true. Sound moves at the rate of about 780 miles an hour, and therefore, on the above supposition, a wind of 7.8 miles per hour could neither retard nor accelerate its velocity more than one per cent., an amount inappreciable to ordinary observation; whereas we know that a wind of the velocity we have mentioned is frequently accompanied with a reduction of the penetrating power of sound of more than 50 per cent.

The explanation of this phenomenon, as suggested by the hypothesis of Professor Stokes, is founded on the fact that in the case of a deep current of air the lower stratum, or that next the earth, is more retarded by friction than the one immediately above, and this again than the one above it, and so on. The effect of this diminution of velocity as we descend toward the earth is, in the case of sound moving with the current, to carry the upper part of the sound-waves more rapidly forward than the lower parts, thus causing them to incline toward the earth, or, in other words, to be thrown down upon the ear of the observer. When the sound is in a contrary direction to the current, an opposite effect is produced,—the upper portion of the sound-waves is more retarded than the lower, which advancing more rapidly, in consequence inclines the waves upward and directs them above the head of the observer. To render this more clear, let us recall the nature of a beam of sound, in still air, projected in a horizontal direction. It consists of a series of concentric waves perpendicular to the direction of the beam, like the palings of a fence. Now, if the upper part of the waves has a slightly greater velocity than the lower, the beam will be bent downward in a manner somewhat analogous to that of a ray of light in proceeding from a rarer to a denser medium. The effect of this deformation of the wave will be cumulative from the sound-center onward, and hence, although the velocity of the wind may have no perceptible effect on the velocity of sound, yet this bending of the wave being continuous throughout its entire course, a marked effect must be produced.

A precisely similar effect will be the result, but perhaps in a considerably greater degree, in case an upper current is moving in an opposite direction to the lower, when the latter is adverse to the sound, and in this we have a logical explanation of the phenomenon observed by General Duane, in which a fog-signal is only heard during the occurrence of a northeast snow-storm. Certainly this phenomenon cannot be explained by any peculiarity of the atmosphere as to variability of density, or of the amount of vapor which it may contain.

The first phenomenon of the class mentioned by General Duane, which I had the good fortune to witness was in company with Sir Frederick Arrow and Captain Webb, of the Trinity House, London, in their visit to this country in 1872. At the distance of two or three miles from an island in the harbor of Portland, Maine, on which a fog-signal was placed, the sound, which had been distinctly heard, was lost on approaching the island for nearly a mile, and slightly regained at a less distance. On examining the position of the fog-signal, which was situated on the farther side of the island from the steamer, we found it placed immediately in front of a large house with rising ground in the rear, which caused a sound-shadow, into which, on account of the lateral divergence of the rays, the sound was projected at a distance, but not in the immediate vicinity of the island. In the same year I made an excursion in one of the light-house steamers, with Captain Selfridge, to an island on the coast of Maine, at which abnormal phenomena were said to have been observed, but on this occasion no variation of the sound was noted, except that which was directly attributable to the wind, the signal being heard much farther in one direction than in the opposite.

PART II.—REMARKS ON SOME ABNORMAL PHENOMENA OF SOUND.*

The communication which I propose to make this evening is brought forward at this time especially on account of the presence of Dr. Tyndall, he being connected with the light-house system of Great Britain, while the facts I have to state are connected with the light-house service of the United States, and must therefore be of interest to our distinguished visitor. The facts I have to present form part of a general report to be published by the United States Light-House Board.

The Light-House Board of the United States has from its first establishment aimed not only to furnish our sea-coast with all the aids to navigation that have been suggested by the experience of other countries and to adopt the latest improvements, but also to enrich the light-house service with the results of new investigations and new devices for the improvement of its efficiency, or, in other words, to add its share to the advance of a system which pertains to the wants of the highest civilization.

Among the obstructions to navigation none are more serious, especially on the American coast, than those caused by fogs.

Fog, as it is well known, is due to the mingling of warmer air surcharged with moisture with colder air, and nowhere on the surface of the earth do more favorable conditions exist for producing fogs than on both our Atlantic and Pacific coasts. On the Atlantic the cold stream of water from the polar regions in its passage southward, on account of the rotation of the earth, passes close along our eastern coast from one extremity to the other, and parallel to this but opposite in direction, for a considerable distance is the great current of warm water known as the Gulf Stream. Above the latter the air is constantly surcharged with moisture, and consequently whenever light winds blow from the latter across the former, the vapor is condensed into fog, and since in summer along our eastern coast the southerly wind prevails, we have during July, August, and September, especially on the coast of Maine, an almost continuous prevalence of fogs so dense that distant vision is entirely obstructed.

On the western coast the great current of the Pacific, after having been cooled in the northern regions, in its passage southward gives rise to cold and warm water in juxtaposition, or, in other words, a current of the former through the latter, and hence whenever a wind blows across the current of cold water, a fog is produced.

From the foregoing statement it is evident that among the aids to navigation fog-signals are almost as important as light-houses. The application however of the science of acoustics to the former is far less advanced than is that of optics to the latter. Indeed, attempts have been made to apply lights of superior penetrating power, as the electric

* Made before the "Philosophical Society of Washington," December 11, 1872.

and calcium lights, to supersede the imperfect fog-signals in use. When however we consider the fact that the absorptive power of a stratum of cloud, which is but a lighter fog, of not more than two or three miles in thickness, is sufficient to obscure the image of the sun, the intensity of the light of which is greater than that of any artificial light, it must be evident that optical means are insufficient for obviating the difficulty in question.

The great extent of the portions of the coast of the United States which are subject to fogs renders the investigation of the subject of fog-signals one of the most important duties of the Light-House Board.

In studying this subject it becomes a question of importance to ascertain whether waves of sound, like those of light, are absorbed or stifled by fog; on this point however, observers disagree. At first sight, from the very striking analogy which exists in many respects between light and sound, the opinion has largely prevailed that sound is impeded by fog. But those who have not been influenced by this analogy have in some instances adopted the opposite opinion—that sound is better heard during a fog than in clear weather. To settle this question definitely the Light-House Board have directed that at two light-houses on the route from Boston to Saint John the fog-signals shall be sounded every day on which the steamboats from these ports pass the station, both in clear and foggy weather, the pilots on board these vessels having, for a small gratuity, engaged to note the actual distance of the boat when the sound is first heard on approaching the signal and is last heard on receding from it. The boats above mentioned estimate their distance with considerable precision by the number of revolutions of the paddle-wheel as recorded by the indicator of the engine, and it is hoped by this means to definitely decide the point in question. We think it probable that fog does somewhat diminish the penetrating power of sound, or in other words, produce an effect analogous to that on the propagation of light. But when we consider the extreme minuteness of the particles of water constituting the fog as compared with the magnitude of the waves of sound, the analogy does not hold except in so small a degree as to be of no practical importance, or, in other words, the existence of a fog is a true, but, we think, a wholly insufficient cause of diminution of sound, which view is borne out by the great distance at which our signals are heard during a dense fog.

Another cause, which without doubt is a true one, of the diminution of the penetrating power of sound is the varying density of the atmosphere, from heat and moisture, in long distances. The effect of this, however, would apparently be to slightly distort the wave of sound rather than to obliterate it. However this may be, we think, from all the observations we have made, the effect is small in comparison with another cause, viz, that of the influence of wind. During a residence of several weeks at the sea-shore, the variation in intensity of the sound of the breakers at a distance of about a mile in no case appeared to be coincident with the variations of an aneroid barometer or a thermometer, but in every instance it was affected by the direction of the wind.

The variation in the distinctness of the sound of a distant instrument as depending on the direction of the wind is so marked that we are warranted in considering it the principal cause of the inefficiency in certain cases of the most powerful fog-signals. The effect of the wind is usually attributed, without due consideration, to the motion of the body of air between the hearer and the sounding instrument; in the case of its coming towards him it is supposed that the velocity of the sound is reinforced by the motion of the air, and when in the opposite direction that it is retarded in an equal degree. A little reflection, however, will show that this cannot be the cause of the phenomenon in question, since the velocity of sound is so vastly greater than that of any ordinary wind that the latter can only impede the progress of the former by a very small percentage of the whole. Professor Stokes, of Cambridge University, England, has offered a very ingenious hypothetical explanation of wind on sound, which we think has an important practical bearing, especially in directing the line of research and subsequent application of principles.

His explanation rests upon the fact that during the passage of a wind between the observer and the sounding instrument the velocity of this will be more retarded at the surface of the earth on account of friction and other obstacles, and that the velocity of the stratum immediately above will be retarded by that below, and so on, the obstruction being lessened as we ascend through the strata. From this it follows that the sound wave will be deformed and the direction of its *normal* changed. Suppose, for example, that the wind is blowing directly from the observer. In this case the retardation of the sound wave will be greater above than below, and the upper part of the wave-front will be thrown backwards so that the axis of the phonic ray will be deflected upwards, and over the head of the observer. If, on the other hand, a deep river of wind (so to speak) is blowing directly towards the observer, the upper part of the front of the wave will be inclined down and towards him, concentrating the sound along the surface of the earth.

The science of acoustics in regard to the phenomena of sound as exhibited in limited spaces has been developed with signal success. The laws of its production, propagation, reflection, and refraction have been determined with much precision, so that we are enabled in most cases to explain, predict, and control the phenomena exhibited under given conditions. But in case of loud sounds and those which are propagated to a great distance, such as are to be employed as fog-signals, considerable obscurity still exists. As an illustration of this I may mention the frequent occurrence of apparently abnormal phenomena. General Warren informs me that at the battle of Seven Pines, in June, 1862, near Richmond,—General Johnston, of the Confederate army, was within three miles of the scene of action with a force intended to attack the flank of the Northern forces, and although listening attentively for the sound of the commencement of the engagement, the battle, which was a severe one, and lasting about three hours, ended without his having heard a single gun. (See Johnston's report.) Another case of a similar kind occurred to General McClellan at the battle of Gaines' Mills, June 27, 1862, also near Richmond. Although a sharp engagement was progressing within three or four miles for four or five hours, the general and his staff were unaware of its occurrence, and when their attention was called to some feeble sound they had no idea that it was from anything more than a skirmish of little importance. (See Report of the Committee on the Conduct of the War.) A third and perhaps still more remarkable instance is given in a skirmish between a part of the Second Corps under General Warren and a force of the enemy. In this case the sound of the firing was heard more distinctly at General Meade's headquarters than it was at the headquarters of the Second Corps itself, although the latter was about midway between the former and the point of conflict. Indeed the sound appeared so near General Meade's camp that the impression was made that the enemy had gotten between it and General Warren's command. In fact so many instances occurred of wrong impressions as to direction and distance derived from the sound of guns that little reliance came to be placed on these indications.

In the report of a series of experiments made under the direction of the Light-House Board by General Duane of the Engineer Corps is the following remark: "The most perplexing difficulty arises from the fact that the fog-signal often appears to be surrounded by a belt varying in radius from one to one and a half miles. Thus in moving directly from a station the sound is audible for the distance of a mile, is then lost for about the same distance, after which it is again distinctly heard for a long time."

Again, in a series of experiments at which Sir Frederick Arrow and Captain Webb, of the Trinity Board, assisted, it was found that in passing in the rear of the opposite side of an island in front of which a fog-signal was placed, the sound entirely disappeared, but by going further off to the distance of two or three miles it reappeared in full force, even with a large island intervening. Again, from the experiments made under the immediate direction of the present chairman of the Light-House Board, with the assistance of Admiral Powell and Mr. Lederle, the light-house engineer, and also from separate experiments made by General Duane, it appears that while a reflector, in the focus of which a steam whistle or ordinary bell is placed, reinforces the sound for a short distance, it produces little or no effect at the distance of two or three miles, and, indeed, the instrument can be as well heard in still air at the distance of four or five miles in the line of the axis of the reflector, whether the ear be placed before or behind it. From these results we would infer that the lateral divergency of sound, or its tendency to spread laterally as it passes from its source, is much greater than has been supposed from experiments on a small scale. The idea we wish to convey by this is that a beam of sound issuing through an orifice, although at first proceeding like a beam of light in paralled rays, soon begins to diverge and spread out into a cone, and at a sufficient distance may include even the entire horizon.

We may mention also in this connection that from the general fact expressed by the divergence of the rays of sound, the application of reflection as a means of reinforcing sound must in a considerable degree of necessity be a failure.

By the application of the principle we have stated and the effect of the wind in connection with the peculiarities of the topography of a region and the position of the sounding body, we think that not only may most of the phenomena we have just mentioned be accounted for, but also that other abnormal effects may be anticipated.

In critically examining the position of the sounding body in the experiment we have mentioned, in which Sir Frederick Arrow and Captain Webb assisted, it was found that the signal was placed on the side of a bank with a large house directly in the rear, the roof of which tended to deflect the sound upwards so as to produce in the rear a shadow, but on account of the divergency of the beam this shadow vanished at the distance of a mile and a half or two miles, and at the distance of, say, three miles the sound of the instrument was distinctly heard. I doubt not that, on examination, all the cases mentioned by General Duane, with one exception, might be referred to the same principle, the exception being expressed in the following remarkable statement in his report to the Light-House Board: "The fog-signals have frequently been heard at a distance of *twenty* miles and as frequently cannot be heard at the distance of *two* miles, and with no perceptible difference in the state of the atmosphere. The signal is often heard at a greater distance in one direction, while in another it will be scarcely audible at the distance of a mile. For example, the whistle at Cape Elizabeth can always be distinctly heard in Portland—a distance of nine miles—during a heavy northeast snowstorm, the wind blowing a gale nearly from Portland towards the whistle."

This is so abnormal a case, and so contrary to generally received opinion, that I hesitated to have it published under the authority of the board until it could be verified and more thoroughly examined. In all the observations that have been made under my immediate supervision, the sound has always been heard farther *with* the wind than against it. It would appear, therefore, from all the observations that the normal effect of the wind is to diminish the sound in blowing directly against it.

There is however a meteorological condition of the atmosphere during a northeast storm on our coast which appears to me to have a direct bearing on the phenomenon in question. It is this: that while a violent wind is blowing from the northeast into the interior of the country, a wind of equal intensity is blowing in an opposite direction at an elevation of a mile or two. This is shown by the rapid eastwardly motion of the upper clouds as occasionally seen through breaks in the lower.

As a further illustration of this principle I may mention that on one occasion (in 1855) I started, on my way to Boston from Albany, in the morning of a clear day, with a westerly wind. The weather continued clear and pleasant until after passing the Connecticut River, and until within fifty miles of Boston. We then encountered a storm of wind and rain which continued until we reached the city. On inquiry I learned that the storm had commenced in Boston the evening before, and, although the wind had been blowing violently towards Albany for *twenty* hours, it had not reached inwardly more than fifty miles. At this point it met the *west* wind and was turned back above in almost a parallel current. This is the general character of northeast storms along our coast, as shown by Mr. Espy, and is directly applicable to the phenomenon mentioned by General Duane, and which, from the frequency with which he has witnessed the occurrence, we must accept as a fact, though by no means a general one applicable to all stations. While a violent wind was blowing towards his place of observation from Cape Elizabeth, at the surface of the earth, a parallel current of air was flowing above with equal or greater velocity in the opposite direction. The effect of the latter would be to increase the velocity of the upper part of the wave of sound, and of the former to diminish it; the result of the two being to incline the front of the wave of sound towards the observer, or to throw it down towards the earth, thus rendering the distant signal audible under these conditions when otherwise it could not be heard. I think it is probable that the same principle applies in other cases to the abnormal propagation of sound.

For the production of a sound of sufficient power to serve as a fog-signal, bells, gongs, &c., are too feeble except in special cases where the warning required is to be heard only at a small distance. After much experience, the Light-House Board has adopted, for first-class signals, instruments actuated by steam or hot-air engines, and such only as depend upon the principle of resonance, or the enforcement of sound by a series of recurring echoes in resounding cavities.

Of these there are three varieties. First, the steam-whistle, of which the part called the bell is a resounding cavity, the sound it emits having no relation to the material of which it is composed; one of the same form and of equal size of wood producing an effect identical with that from one of metal. Another variety is the fog-trumpet, which consists of a trumpet of wood or metal actuated by a reed like that of a clarionet. The third variety is called the siren trumpet, which consists of a hollow drum, into one head of which is inserted a pipe from a steam-boiler, while in the other head a number of holes are pierced, which are alternately opened and shut by a revolving plate having an equal number of holes through it. This drum is placed at the mouth of a large trumpet. The sound is produced by the series of impulses given to the air by the opening and shutting of the orifices and consequent rushing out at intervals with explosive violence of the steam or condensed air. The instrument, as originally invented by Cagniard de Latour, of France, was used simply in experiments in physics to determine the pitch of sound; but Mr. Brown, of New York, after adding a trumpet to it, and modifying the openings in the head of the drum and the revolving plate, offered it to the Light-House Board as a fog-signal, and as such it has been found the most powerful ever employed.

In ascertaining the penetrating power of different fog-signals, I have used with entire success an instrument of which the following is a description: A trumpet of ordinary tinned iron of about 3 feet in length, and 9 inches in diameter at the larger end, and about 1 inch at the smaller, is gradually bent so that the axis of the smaller part is at right angles to the axis of the larger end; on the smaller end is soldered a cone, of which the larger end is about 2 inches in diameter. Across the mouth of this cone is stretched a piece of gold-beater's skin. When the instrument is used, the opening on the larger end is held before the instrment to be tested, the membrane being horizontal, and the mouth of the trumpet vertical; over the membrane is strewed a small quantity of fine sand, which is defended from the agitation of the air by a cylinder of glass, the upper end of which is closed by a lens. When the instrument under examination is sounded, being sufficiently near the sand, is agitated; it is then moved further off, step by step, until the agitation just ceases; this distance, being measured, is taken as the relative penetrating power of the sounding instrument. The same process is repeated with another sounding instrument, and the distance at which the sound ceases to produce an effect on the sand is taken as the measure of the penetrating power of this instrument, and so on. On comparing the results given by this instrument with those obtained by the ear on going out a sufficient distance, the two are found to agree precisely in their indications. The great advantage in using this contrivance is that the relative penetrating power of two instruments may be obtained within a distance of a few hundred yards, while to compare the relative power of two fog-signals by the ear requires the aid of a steamer and a departure from the origin of sound in some cases of 15 or 20 miles.

PART III.—INVESTIGATIONS DURING 1873 AND 1874.*

OBSERVATIONS ON SOUND AND FOG-SIGNALS, IN AUGUST, 1873.

Professor Henry, chairman, and Commander Walker, naval secretary of the Light-House Board, left Portland August 12th, 1873, at 3 o'clock P. M. in the steam-tender Myrtle, Captain Foster, for Whitehead light-station, at which place abnormal phenomena of sound had been observed.

* From the Report of the Light-House Board, for 1874.

Whitehead light-station is on a small island about a mile and a half from the coast of Maine, on the western side of the entrance to Penobscot Bay, and in the direct line of the coasting-steamers and other vessels from the westward bound into the Penobscot Bay and River. The light-house and fog-signal are situated on the southeast slope of the island, the surface of which consists almost entirely of rock, the middle being at an elevation of 75 feet above the mean tide-level.

The phenomena which had been observed at this and other stations along the coast consisted of great variation of intensity of sound while approaching and receding from the station. As an example of this we may state the experience of the observers on board the steamer City of Richmond on one occasion, during a thick fog in the night in 1872. The vessel was approaching Whitehead from the southwestward, when, at a distance of about six miles from the station, the fog-signal, which is a 10-inch steam-whistle, was distinctly perceived and continued to be heard with increasing intensity of sound until within about three miles, when the sound suddenly ceased to be heard, and was not perceived again until the vessel approached within a quarter of a mile of the station, although from conclusive evidence furnished by the keeper it was shown that the signal had been sounding during the whole time. The wind during this time was from the south, or approximately in an opposite direction to the sound. Another fact connected with this occurrence was that the keeper on the island distinctly heard the sound of the whistle of the steamer, which was commenced to be blown as soon as the whistle at the station ceased to be heard, in order to call the attention of the keeper to what was supposed to be a neglect of his duty in intermitting the operations of his signal. It should be observed in this case that the sound from the steamer was produced by a 6-inch whistle, while that of the station was from an instrument of the same kind of 10 inches in diameter; or, in other words, a lesser sound was heard from the steamer, while a sound of greater volume was unheard in an opposite direction from the station. It is evident that this result could not be due to any mottled condition or want of acoustic transparency of the atmosphere, since this would absorb the sound equally in both directions. The only plausible explanation of this phenomenon is that which refers it to the action of the wind. In the case of the sound from the steamer, the wind was favorable for its transmission, and hence it is not strange that its sound should be heard on the island when the sound from the other instrument could not be be heard on the steamer. To explain on the same principle the fact of the hearing of the sound at the distance of six miles, and afterward of losing it at the distance of three miles, we have only to suppose that in the first instance the retarding effect of the wind was small, and that in the second it became much greater on account of a sudden increase in the relative velocity of the current in the upper and lower portions.

After making a critical examination of the island and the position of the machinery, and also in regard to any obstacle which might interfere with the propagation of the sound, the keeper was directed to put the instrument in operation and to continue to sound it for at least two hours, or until the steamer was lost sight of, which direction was complied with. In passing from the island, almost directly against a light wind, the intensity of the sound gradually diminished as a whole, with the increase of distance, but varied in loudness from blast to blast, now louder, then again more feeble, until it finally ceased at a distance of about fifteen miles, as estimated by the intervals between the blasts and the sight of the steam as seen through a spy-glass, and also from points on the Coast-Survey charts.

The result of this investigation clearly showed the power of the apparatus in propagating sound under conditions not entirely favorable, since the wind, though light, was in opposition to the sound.

Cape Elizabeth Light-Station, Maine, August 29, 1873.—The fog-signal at this place is on a prominent headland to which the course of all vessels is directed when bound from the southward into Portland Harbor. It is furnished with two light houses 919 feet apart and 143 feet above sea-level. The easterly tower is connected with the keeper's dwelling by a wooden-covered way 200 feet long and about 12 feet high; the station is furnished with a 10-inch steam fog-whistle, placed to the southward of the easterly tower, at a distance of about 625 feet and about at right angles with the covered way; it therefore has a background, including the covered way, of about 65 feet above the height of the whistle, which was found to reflect a perceptible echo. The whistle was actuated by steam at 55 pounds pressure, consuming from 60 to 65 pounds of anthracite coal per hour. The whistle itself differs from the ordinary locomotive-whistle by having a projecting ledge or rim around the lower part through which the sheet of steam issues to strike against the lower edge of the bell. What effect this projecting ledge or rim may have is not known to the observers. This whistle is provided, (for the purpose of concentrating the sound in a given direction,) with a hollow truncated pyramid 20 feet long, 10 feet square at the large end, and 2½ feet square at the small end, the axis of the pyramid being placed parallel to the horizon, with the whistle at the smaller end. In order to ascertain the effect of this appendage to the whistle the simplest plan would have been to have noted the intensity of sound at various points on a circle of which the whistle would have been the center. This being impracticable on account of the intervention of the land, the observations were confined to points on the three arcs of a circle of about 120°, of which the axis divided the space into 80° and 40° and a radius of one, two, and three miles. The result of these observations was that, starting from the axis of the trumpet on the east side, the sound grew slightly less loud until the prolongation of the side of the trumpet was reached, when it became comparatively faint and continued so until the line between the whistle and observer was entirely unobstructed by the side of the trumpet, when the sound was apparently as loud as in the prolongation of the axis itself. On the west side of the axis of the trumpet the sound in a like manner diminished from the axis until the prolongation of the side of the trumpet was reached, when it became feeble again, slightly increased, and then gradually diminished until the line of direction made an angle of about 80° with the axis of the trumpet, when it ceased to be heard at a distance of about one and a half miles. It should be observed, however, that at this point the line of sight of the observers was obstructed by the side of the trumpet and the smoke-stack of the boiler. The wind was light, at south-southwest, approximately in direct opposition to the direction of the sound when it ceased to be heard. We are informed that complaints had previously been made by officers of steamers passing near this point that the sound was here inaudible previous to the introduction of this trumpet; it would therefore follow that it is of no use in increasing the effect on the western side of the axis and is of injury to the sound on the lines of prolongation of its sides. If the sound ceased to be heard at the point mentioned, when the trumpet is removed the only apparent cause of the phenomenon will be the prevailing direction of the wind, which, coming from the southwest, will be in opposition to the sound of the whistle; but in the case of the present investigation the force of the wind was so small that it scarcely appeared adequate to produce the effect, and this question, therefore, must be left for further investigation. It may be important to state that in the case where the sound ceased to be heard it was regained by sailing directly toward the station about one mile, or at half a mile from the station. After making the foregoing observations as to the intensity of sound in different directions from the station, the observations were closed by sailing directly along the axis of the trumpet until the sound, which gradually grew fainter as the distance increased, finally ceased to be heard at a distance of about nine miles. In comparing this last result with an instrument of about the same power at Whitehead, which gave a perceptible sound at a distance of fifteen miles, the only apparently variable circumstance was the velocity of the wind, in both cases adverse to the direction of the sound; but in that of Cape Elizabeth it was of considerable more intensity.

During the foregoing experiments, when the vessel was about a mile from the station, steaming directly outward, in the prolongation of the axis of the instrument, there was heard after each sound of the whistle a distinct echo from the broad, unobstructed ocean, which was attributed at the time, as in other cases, to reflections from the crests and hollows of the waves, a similar phenomenon having since been referred to a reflection from air of a different density. This observation becomes important in regard to the solution of the question as to the abnormal phenomena of sound.

Cape Ann Light-Station, Massachusetts, August 31, 1873.—This is one of the most important stations on the New England coast. It is furnished with two first-order lights, and a 12-inch steam-whistle, actuated by 60 pounds pressure of steam. The present is the fourth engine which has been erected at this station, in consequence of the complaints either as to the inefficiency of the sound or its failure to be heard in certain directions. It was at first proposed to sail entirely around the island in order to test the intensity of the sound in different directions, but this was found impracticable on account of want of depth of water on the inland side; the observations were therefore confined to the direction in which complaints had been made as to the deficiency of the signal, namely, in a southerly direction. The result of these observations, the points of which included an arc of 120°, was that the sound was heard with equal intensity except when the direction of the station was to the northward and eastward of the observers; then, in one instance, the sound became very indistinct, and in another was entirely lost, both at a distance of about two miles. In these cases the line of sight between the observers and the signal was interrupted, in the first by a small building, the gable-end of which was within 10 feet of the whistle, and in the second by the south light-tower, which is within 30 feet of the whistle. In this series of experiments, as with the last, the wind was against the sound; the effect was noted by passing over the arc several times at different distances. The wind was from the southward and westward and very light, and the sound was finally lost at about six miles, and in the direction of the obstructions.

Boston Light-Station, August 31, 1873.—The light-house is situated on a low, rocky island, on the north side of the main outer entrance to Boston Harbor, nine miles from the city. It is furnished with three caloric engines, two of the second class and one of the first. The two second-class engines are so arranged as to act separately or together, and in the latter arrangement serve to duplicate the larger engine. At the time the observations were made, the larger engine was about being repaired, and one of the smaller engines with the double air-reservoir was used. The larger engine is used with 12 pounds pressure of air, which falls to 8 pounds in producing the sound. The smaller engine, with the double reservoir, is started with 9 pounds pressure, which falls to 8 pounds. This difference in the pressure of air in the two engines is caused by the larger ratio of the reservoir to the size of the reed. With a greater pressure than 12 pounds to the square inch in the larger engine and 9 pounds in the smaller no sound is produced; the reed is unable to act against the pressure, and, consequently, the orifice remains closed. The trumpet of the larger of the engines is reported to have been heard eighteen miles at sea, which, in consideration of the results obtained at Whitehead, we thought very probable. The time required, from starting fires, to get a good working-pressure, is about half an hour. The amount of coal consumed per hour is 17 pounds.

There is moreover at this station a bell, operated by a Stevens clock, not at present used. It is placed on a high, wooden frame-structure, on which one of the ancient bell-striking machines was originally erected. The most proper position for the fog-signal is on the ground occupied by this bell-tower, but as this was not removed at the time of the erection of the trumpets, they were placed in such positions as to have the line of sound interrupted to the northeastward by the bell and light towers. It was therefore thought probable that this was the cause of the deficiency of sound in this direction. To test this the vessel was caused to traverse the arcs of several concentric circles, in the portion of the horizon where the sound was most required as a signal. The first arc traversed was about one and one-half miles from the signal. The vessel on this crossed the axis where the sound was quite loud, and proceeded northward until the sight of the trumpet was obscured by the beforementioned towers, when the sound became almost inaudible. The vessel next returned across the axis, on a circle of about three miles radius, with similar results; but after crossing the axis the sound on the southern side continued to be but little diminished in intensity along an arc of two and a half miles, or as far as the land would allow the vessel to go. The vessel was next put upon an arc, of which the radius was one and a half miles, and on the south side of the axis, and sailed to the northward until the axis was reached, it was then turned and ran for the entrance of the harbor, hugging the southern shore, keeping as far from the signal as possible. Throughout this passage the sound was clear and loud, showing very little, if any, diminution of power as the several positions deviated more and more from the direction of the axis, until the vessel was at right angles with the axis, the land not permitting any greater distance. The vessel approached to within three-quarters of a mile of the signal and then continued still farther around, until nearly in the rear of it, the sound still continuing clear and loud. The vessel next proceeded up the harbor, nearly in the line of the axis of the trumpet prolonged in the rear, still continuing to hear the signal distinctly until the keeper, losing sight of the vessel, stopped sounding the instrument. These observations were made under very favorable circumstances, it being nearly calm. What wind did exist was about equally favorable to points on either side of the axis. The inference from these observations is, first, that small objects placed near the source of sound tend to diminish its intensity in the direction of its interruption, and should, therefore, if possible, be removed, or the instrument so placed as to obviate such obstructions; and, second, that, even with the trumpet, the sound so diverges from the axis as to be efficient even in the rear of the instrument.

OBSERVATIONS ON FOG-SIGNALS, AUGUST 25, 1874.

The first of these was on board the steamer Putnam, at Little Gull Island, with Admiral Trenchard, inspector of lights of the third district, accompanied by Governor Ingersoll, of Connecticut, and Captain Upshur, U. S. N.

At this place are two sirens, the one to replace the other in case of an accident. One of the sirens was sounded with the pressure of 50 pounds per square inch. The wind was across the axis of the trumpet, and almost precisely at right angles to it.

The steamer was headed against the wind; on a line at right angles to the axis of the trumpet. The sound in this case also travelled against the wind, which was at an estimated velocity of from 4 to 5 miles per hour. The distance travelled before the sound became inaudible was estimated, by the speed of the steamer, at 3½ miles.

The steamer was next headed in an opposite direction and returned along its previous path, across the mouth of the trumpet of the siren, the sound gradually increasing in strength without any marked irregularity, until the siren was reached, and on leaving this, the course remaining the same, the sound gradually diminished in intensity, but with less rapidity than before, until it was finally lost at a distance of 7½ miles. In the latter instance the movement of the sound was with the wind. The result of these observations was conformable to that generally obtained from previous observations, namely, that the sound is seldom or never heard at the same distance in different directions, and, moreover, that it is generally heard farther with the wind than against it.

The observations of this day also illustrate the spread of the sound-wave on either side of the axis of the trumpet, a fact which has frequently been observed in other investigations. It may be well to mention that the siren trumpet at this locality is directed horizontally with its prolonged axis passing over, immediately in front of the mouth of the trumpet, a space of very rough ground, the surface of which is principally composed of bowlders, one of which, of very large size, is directly in front of the trumpet, and the idea occurred to me that this rough surface might produce some effect on the transmission of sound to a distance. I observed by strewing sand upon a paper that the former was violently agitated when held near the surface of the large bowlder just mentioned, during the blast of the siren trumpet.

At this station, during the visit of Sir Frederick Arrow, the sound was lost in the direction of the axis of the trumpet at a distance of two miles, and then again regained with distinctness at the light-vessel, a distance of four and one-half miles; this was what we have denominated as an abnormal phenomenon, which we think was due to a slight variation in the velocity of the lower or upper part of the current of air, but, unfortunately, the demand for the use of the vessel as a light-house tender prevented the attempt to ascertain whether the same phenomenon would be observed a second time and to further investigate its cause.

The second investigations this season were September 1, 1874, with General Barnard, of the Light-House Board, and General Woodruff, engineer of the third district. We proceeded on this occasion in the steamer Mistletoe to Block Island, one of the outer stations of the Light-House Board, fully exposed, without intervention of land, to the waves and storms of the ocean.

On the southerly side of this island a light-house is about being erected, and a siren station at this locality had been established and was in full operation.

There are here two sirens attached to one boiler, one to be used in case of an accident to the other. For the sake of experiment they are of slightly different qualities, one with a larger trumpet with a revolving disk of the old pattern, giving a lower tone; the other a smaller trumpet, having a revolving disk with openings allowing a much more sudden full blast of steam, and revolving with greater velocity so as to give a higher pitch. The latter is far the superior instrument, as was evident to us by the sound which it produced, and as had been established by the use of the artificial ear in the manufactory of Mr. Brown. The effect on the unguarded ear was scarcely endurable, and the very earth around appeared to tremble during the blast. The keeper (an intelligent man who has been promoted from the station of assistant keeper at Beaver Tail light to this station) informed us that a fleet of fishing-vessels coming in distinctly heard it at a distance estimated by their rate of sailing at scarcely less than thirty miles; this was on two separate occasions. The keeper had been directed to note and record the date at which he heard the sound from other signals; he reported that he had frequently heard the fog-signal at Point Judith, a distance of seventeen miles, and that the observer at the latter place frequently heard his signal; but on comparing records the two sounds had not been heard simultaneously by the two keepers; when it was heard from one station it was not heard from the other, illustrating again the general rule that sound is not transmitted simultaneously with equal intensity in opposite directions.

This occasion also furnished very favorable conditions for observing the remarkable phenomenon of the ocean-echo. At the cessation of each blast of the trumpet, after a slight interval, a distinct and prolonged echo was returned from the unobstructed ocean. It is important to observe, in regard to this phenomenon, that the siren is placed near the edge of a perpendicular cliff, at an elevation of from 75 to 100 feet above the ocean, and, furthermore, that the direction of the wind formed an angle of about 35° with the axis of the trumpet. Now, the loudness of this echo was not the greatest at the siren-house, but increased in intensity until a point was reached several hundred yards from the trumpet, approximately more in accordance with a reflection from the waves. The wind was blowing from the shore with the direction of the sound as it went off from the trumpet, and nearly against it on the return of the echo. I have attributed this phenomenon, which was first observed in 1866 at East Quoddy Head on the coast of Maine, and since at various stations, at which the trumpet or siren has been used, to the reflection of the sound from the crests and slopes of the waves, and the observation we have mentioned would appear to favor this hypothesis. In connection with this explanation, I may mention that my attention has been called by General Meigs, of the United States Army, to an echo from the palings of a fence, and also from a series of indentations across the under side of the arch of one of the aqueduct bridges of the Washington water-works. The fact that the sound was much louder at a point considerably distant from the trumpet was noted by one of the party entirely unacquainted with the hypothesis.

The keeper at this station confirmed without a leading question the statement of Captain Keeney, that it frequently happens that a feeble sound of a distant object, as the roar of the surf, can be heard against the direction of the wind, and that in this case it always betokens a change in the weather, and is, in fact, used generally by the fishermen as a prognostic of a change in the direction of the wind, which will, in the course of a few hours, invariably spring up from an opposite quarter. In such case, it is highly probable, as has been stated, that a change has already taken place in the direction of the upper strata of the air, although, from theoretical considerations, we might infer that the same result would be produced if the wind were stationary above and moving with a considerable velocity in a direction opposite to the sound at the surface of the earth, the velocity gradually diminishing as we ascend, for in this case, also, the inclination of the sound waves would be downward.

The third series of investigations, September 23, 24, 1874, was made in company with Captain John Davis and Major Hains, both of the Light-House Board, and General Woodruff, engineer of the third district, and Mr. Brown, patentee of the siren. For the purpose three light-house tenders were employed, viz: Mistletoe, Captain Keeney; Putnam, Captain Field; Cactus, Captain Latham.

The place of operation chosen for the first day's series was about 1½ miles from the northern point of Sandy Hook.

From the experience gained by the accumulated observations which had been made, it was concluded that the phenomena of sound in regard to perturbing influences could not be properly studied without simultaneously observing the transmission of sound in opposite directions. It was therefore concluded to employ at least two steamers in making the investigations.

In regard to this point the commission was fortunate in being able to command the use, for a limited period, of the three tenders mentioned above, which happened to be at the time assembled at the light-house depot, Staten Island, and could be spared from their ordinary operations for a few days without detriment to the service. It was also fortunate in selecting for the scene of the investigations an unobstructed position in the lower bay of New York, and perhaps still more fortunate in the season of the year when, on account of the heat of the sun, a land and sea breeze, which changed its direction at a particular hour of the day, enabled results to be obtained bearing especially on the phenomena to be investigated.

Attention was first given to the character of the several steam-whistles which were intended to be used as the sources of the sound during the series of investigations.

These whistles, which were sounded during the whole of the observations with 20 pounds of steam on each boiler, gave at first discordant sounds, and were found by their effect upon an artificial ear to be considerably different in penetrating power; they were then adjusted by increasing or diminishing the space between the bell and the lower cylinder by turning a screw on the axis of the bell intended for that purpose, until they produced the same effect upon the sand in the membrane of the artificial ear; but in order to further be insured of the equality of the penetrating power of the several whistles, the three steamers abreast, forming as it were a platoon, were directed to proceed against the wind, sounding all the time in regular succession—the Cactus first, then, after an interval of a few seconds, the Mistletoe, and then the Putnam—until the stationary observers lost the sound of each. They became inaudible all very nearly at the same moment. The sound of the Putnam was thought to be slightly less distinct; it was therefore chosen as a stationary vessel, from which the observations of the sound of the other two were to be made.

The Putnam being anchored at the point before mentioned, arrangements were made for sending off the other two vessels in opposite directions, one with and the other against the wind, with instructions to return when the sound became inaudible to those on the stationary vessel, this to be indicated by a flag-signal. It should be mentioned that the velocity of the wind was measured from time to time during the subsequent experiments with one of Robinson's hemispherical cup anemometers, made by Casella, of London. The velocity of the wind first observed by this instrument, just before the starting of the vessels, was 6 miles per hour, the instrument being freely exposed on the paddle-boxes of the steamer. A sensitive aneroid barometer marked 30.395 in. and continued to rise gradually during the day to 30.43 in. the temperature was 71° F.

The vessels left at 11:18 A. M. the wind being from the west, Captain Davis taking charge of the sounding of the whistle on the Cactus, which proceeded east with the wind, the sound coming to the ear of the observer against the wind; while the sounding on the Mistletoe was in charge of General Woodruff, and, as the vessel steamed against the wind, the sound came to the observers on the stationary vessel with the wind; the other members of the party remained on the Putnam, at anchor at the point before mentioned, off the Hook, Major Hains having charge of the signals. The sound of the first of the vessels was heard faintly at 14 minutes after leaving, but not heard at 16 minutes; we may therefore assume that it became inaudible at 15 minutes. And within a minute of the same time, by a mistake of the signal, the other ceased to advance, and commenced to come back; the sound from it, however, was very distinct, while at the same moment the sound from the other was inaudible. On account of the mistake mentioned, the relative distance at which the sounds from the two vessels might have become inaudible cannot be accurately given; but the fact observed, that the sound which came with the wind was much more audible than the other, is in conformity with the generally observed fact that sound is heard farther with the wind than against it. In the mean time the velocity of the wind had sunk to 1½ miles per hour.

Next, the vessels, leaving at 11:55 A. M. changed positions; the Cactus, under Captain Davis, steamed west, directly in the direction from which the wind came, while the Mistletoe, under General Woodruff, steamed east, directly before the wind. The result of this trial was well marked in all respects; the sound of the Mistletoe was lost in 9 minutes, which, from the speed of the steamer, was estimated at about 1½ miles, while the sound of the Cactus was heard distinctly for 30 minutes, or at an estimated distance of 5 miles. The wind at the middle of this trial had sunk to 0.42 mile per hour, or nearly to a calm. The result of this trial was somewhat abnormal, for though the wind had sunk nearly to a calm, the sound was still heard three times as far in the direction of the slight wind as against it.

After a lapse of an hour and a half a third trial was made; in the mean time the wind had changed within two points of an exactly opposite direction, blowing, from the indications of the anemometer, at the rate of ten and one-half miles per hour.

The Cactus again steamed in the eye of the wind, which was now however from nearly an opposite point of the compass, while the other vessel steamed in an opposite direction. The sound of the Cactus was lost at the end of twenty-seven minutes, with the wind, or at a distance of four and a half miles.

The sound of the Mistletoe was lost at the end of thirty minutes, or at a distance of five miles, moving against a brisk wind then blowing.

This result was entirely unexpected and much surprised every member of the party, since it was confidently expected that an increase in the intensity of the wind of more than ten miles per hour, and a change to the opposite direction, would materially affect the audibility of the sound, and give a large result in favor of the sound, which moved in the same direction with the wind, but this was not the case. In the course of all the observations in several years in which investigations have been carried on under the direction of the chairman of the board, this is the only instance in which he had heard a sound at a greater distance against the wind than with it, although, as before stated, a number of cases have been reported by other observers in which, under peculiar conditions of the weather, this phenomenon has been observed.

To briefly recapitulate the results, we have in this case three instances, in succession, in which a sound was heard farther from the west than from the east, although in the mean time the wind had changed to nearly an opposite direction. Had these results been deduced from the first observations made on the influence of wind on sound, or, in other words, without previous experience, the conclusion would have been definitely reached that something else than wind affected the conveyance of sound, and this conclusion would have been correct, if the suggestion had been confined to the wind at the surface; but from previous observations and theoretical conclusions, the observed phenomena are readily accounted for by supposing that during the whole time of observation the wind was blowing from the west in the higher part of the aerial current, and that the calm and opposing wind observed were confined to the region near the surface. To test this hypothesis, Major Hains constructed a balloon of tissue-paper, which, after being completed, was unfortunately burned in the attempt to inflate it with heated air.

The remainder of this day was devoted to observations on the sound of the siren at the light-house at Sandy Hook. For this purpose the Cactus, under Captain Davis, was directed to steam in the eye of the wind, while the Mistletoe, under General Woodruff, steamed before the wind, and the Putnam steamed at right angles to the wind. Unfortunately, on account of the diminution of light at the closing in of the day, nothing could be observed. The only result obtained was that one of the duplicate sirens was heard more distinctly than the other, namely, the one with the higher note.

Experiments September 24, 1874.—The place chosen for the observations of this day was still farther out in the ocean, at the Sandy Hook light-vessel, 6 miles from the nearest point of land. The pressure of the atmosphere was a little greater than the day before, being 30.52; the temperature about the same, 72° Fahr. wind light, from a westerly direction, as on the previous day, with a force, as indicated by the anemometer, of 1.2 miles per hour. Having been provided with a number of India-rubber toy balloons, the two vessels were sent off in opposite directions—the Mistletoe toward the west, against the wind, the Cactus toward the east, with the wind, leaving at 10:40 A. M. A change was also made in observing the sound. In these observations the sound was noted at each vessel from the other, the speed of the steamers being the same; the distance between them when the Mistletoe lost the sound of the Cactus was two miles, while the Cactus continued to hear the Mistletoe's sound coming with the wind until they were four miles apart. Simultaneously with this observation a balloon was let off from the Putnam at the light-vessel, which, in its ascent, moved continuously obliquely upward in a line slightly curving toward the horizon, in the direction of the wind at the surface, as far as it could be followed with the eye, indicating a wind in the same direction in the several strata through which it passed, but of a greater velocity in the upper strata.

The vessels now changed places, the Cactus steaming west, the Mistletoe east, the wind having entirely ceased at the surface of the earth. In this case the Cactus lost the sound of the Mistletoe when the vessels were two miles apart, while the Mistletoe continued to hear the sound of the Cactus until they were three miles apart. A balloon let off ascended vertically until it attained an elevation of about one thousand feet, when, turning east, it followed the direction of the previous one. The sound in this case from the east was heard three miles, while that from the west was heard two miles, while in the preceding observations the distances were as 2 to 1; the only changing element, as far as could be observed, was that of the wind at the surface, which became less.

Third trial, 12:45 P. M.—The wind previous to this trial had changed its direction 10 points or about 112½° round through the south, and as indicated by the anemometer at a velocity of 4.8 miles per hour. In this case the Cactus, going against the wind, lost the Mistletoe's sound coming to her against the wind when the vessels were 1 mile apart, while the Mistletoe heard the Cactus, the sound coming to her with the wind when the vessels were 1⅞ miles apart. The several balloons set off at this time were carried by the surface wind westwardly until nearly lost to sight, when they were observed to turn east, following the direction of the wind observed in the earlier observations. The results of the whole series of observations are extremely interesting. In all the experiments the difference in the audibility of the sound in different directions was very marked, and indeed it rarely happens that the sound is equal in two directions, although from the hypothesis adopted this may be possible, since, according to this hypothesis, both the upper and lower currents have an influence upon the audibility of sound in certain directions. From the first trial, the motion of the air being in the same direction both below and above, but probably more rapid above than below on account of resistance, the upper part of the sound-wave would move more rapidly than the lower, and the wave would be deflected downward, and therefore the sound, as usual, heard farther with the wind than against it. In the third experiment of the same day, in which the wind changed to an almost opposite direction, if the wind remained the same above, as we have reason to suppose it did from the observations on the balloons on the second day, the sound should be heard still farther in the same direction or against the wind at the surface, since, in this case, the sound-wave being more retarded near the surface would be tipped over more above and the sound thus be thrown down.

The observations of the second day are also in conformity with the same hypothesis, the change in the wind being probably due to the heating of the land, as the day advanced, beyond the temperature of the water, and thus producing a current from the latter to the former, while the wind observed in the morning from the west was the land-wind due to the cooling of the latter.

In the morning the wind was blowing from the west both in the higher strata and at the surface of the earth, and in this condition the sound was heard farther with the wind than against it.

The wind at the surface about midday gradually ceased, and shortly afterward sprang up from an east direction; in this condition the sound, with the wind at the surface, was heard at a greater distance. This is also in strict conformity with the theory of a change in the form of the sound-wave, as in the latter case the lower portion would be retarded, while the upper portion of the wave would be carried forward with the same velocity, and hence the sound would be thrown down on the ear of the observer. To explain the result of the third trial of the second day, we have only to suppose that the influence of the upper current was less than that of the lower. The conditions for these observations were unusually favorable, the weather continuing the same during the two days, and the change of the wind also taking place at nearly the same hour.

The fact thus established is entirely incompatible with the supposition that the diminution in the sound is principally caused by a want of homogeneity in the constitution of the atmosphere, since this would operate to absorb sound equally in both directions.

In May, 1873, Professor Tyndall commenced a series of investigations on the subject of the transmission of sound, under the auspices of the Trinity House, of England, in which whistles, trumpets, guns, and a siren were used, the last-named instrument having been lent by the Light-House Board of the United States to the Trinity House for the purpose of the experiments in question. The results of these investigations were, in most respects, similar to those which we had previously obtained. In regard to the efficiency of the instruments, the same order was determined which has been given in this report, namely, the siren, the trumpet, and the whistle. Professor Tyndall's opinion as to the efficiency of the siren may be gathered from the following remarks. Speaking of the obstruction of sound in its application as a fog-signal, he says, "There is but one solution of this difficulty, which is to make the source of sound so powerful as to be able to endure loss and still retain sufficient residue for transmission. Of all the instruments hitherto examined by us the siren comes nearest to the fulfillment of this condition, and its establishment upon our coasts will, in my opinion, prove an incalculable boon to the mariner." Professor Tyndall arrived at the conclusions which the information we had collected tended to establish, that the existence of fog, however dense, does not materially interfere with the propagation of sound; and also that sound is generally heard farther with the wind than against it, although the variation of the intensity of the sound is not in all cases in proportion to the velocity of the wind. The result of his investigations in regard to the pitch of sound was also similar to those we have given; and, indeed, all the facts which he has stated are, with a single exception as to the direction of the echo, in strict accordance with what we have repeatedly observed. We regret to say, however, that we cannot subscribe to the conclusions which he draws from his experiments as to the cause of the retardation of sound that it is due to a flocculent condition of the atmosphere, caused by the intermingling with it of invisible aqueous vapor.

That a flocculent condition of the atmosphere, due to the varying density produced by the mingling of aqueous vapor, is a true cause of obstruction in the transmission of sound is a fact borne out by deduction from the principles of wave-motion, as well as by the experiments of the distinguished physicist of the Royal Institution of Great Britain; but from all the observations we have made on this subject we are far from thinking that this is the efficient cause of the phenomena under consideration. A fatal objection, we think, to the truth of the hypothesis Professor Tyndall has advanced is that the obstruction to the sound, whatever may be its nature, is not the same in different directions. We think we are warranted in asserting that in the cases of acoustic opacity which he has described, if he had simultaneously made observations in an opposite direction, he would have come to a different conclusion. That a flocculent condition of the atmosphere should slightly obstruct the sound is not difficult to conceive; but that it should obstruct the ray in one direction and not in an opposite, or in a greater degree in one direction than in another, the stratum of air being the same in both cases, is at variance with any fact in nature with which we are acquainted. We would hesitate to speak so decidedly against the conclusions of Professor Tyndall, for whose clearness of conception of physical principles, skill in manipulation, and power of logical deduction we entertain the highest appreciation, were the facts which were obtained in our investigations of a less explicit character.

While the phenomena in question are incompatible with the assumption of a flocculent atmosphere as a cause, they are in strict accordance with the hypothesis of the refraction of the waves of sound due to a difference in velocity in the upper and lower portions of the currents of air. We do not say, however, that the transmission of sound in the atmosphere is fully investigated, or that the abnormal phenomena which are said to have been observed in connection with fog-signal stations have been fully explained. So far from this, we freely admit we are as yet in ignorance as to how the hypothesis we have adopted is applicable to the critical explanation of the obstruction to sound in the abnormal cases mentioned by General Duane. We feel, however, considerable confidence in its power to afford a rational explanation of these phenomena when the conditions under which they exist shall have been accurately determined.

We are farther confirmed in our conclusion by the publication of an interesting paper in the proceedings of the Royal Society by Professor Osborne Reynolds, of Owens College, Manchester, intended to show that sound is not absòrbed by the condition of the atmosphere, but refracted in a manner analogous to the hypothesis which has been adopted in the preceding report.

Much further investigation is required to enable us to fully understand the effects of winds on the obstruction of sound, and to determine the measure of the effect of variations of density in the air due to inequality of heat and moisture. But such investigations can only be made under peculiar conditions of weather and favorable localities, with the aid of a number of steamers, and a series of observers, by whom the transmissibility of the air may be simultaneously observed in different directions. The position which we were so fortunate to obtain in our experiments in the lower bay of New York at the season of the prevalence of land and sea breezes was exceptionally favorable for the study of the action of wind upon sound. It is the intention of the Light-House Board to continue observations in regard to this matter, and to embrace every favorable opportunity for their prosecution under new and varied conditions.

LIGHT-HOUSE BOARD, *October*, 1874.

PART IV.—INVESTIGATIONS IN 1875.*

PRELIMINARY REMARKS.

In the Appendix to the Light-House Report of 1874 I gave an account of a series of investigations relative to fog-signals, which had been made at different times under the direction of the chairman of the committee on experiments.

These investigations were not confined to the instruments for producing sound, but included a series of observations on sound itself, in its application to the uses of the mariner. In the course of these investigations the following conclusions were early arrived at:

1st. That the rays of a beam of loud sound do not, like those of light, move parallel to each other from the surface of a concave reflector, but constantly diverge laterally on all sides; and, although at first they are more intense in the axis of the reflector, they finally spread out so as to encompass the whole horizon, thus rendering the use of reflectors to enforce sound for fog-signals of little value.

2d. That the effect of wind in increasing or diminishing sound is not confined to currents of air at the surface of the earth, but that those of higher strata are also active in varying its transmission.

3d. That although sound is generally heard farther with the wind than against it, yet in some instances the reverse is remarkably the case, espec-

* From the Report of the Light-House Board, for 1875.

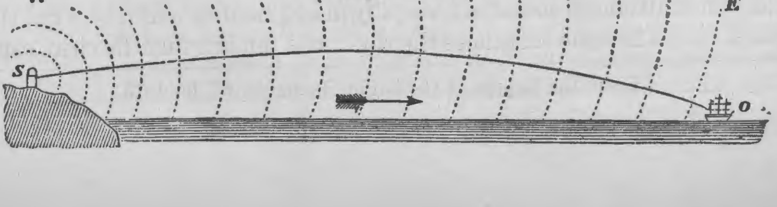
ially in one locality; in which the sound is heard against a northeast snow-storm more distinctly than when the wind is in an opposite direction. This anomaly was referred to the action of an upper current in an opposite direction to that at the earth, such a current being known to exist in the case of northeast storms on our coast. But in what manner the action of the wind increased or diminished the audibility of sound was a problem not solved. It could not be due, as might be thought at first sight, to the acceleration of the sonorous impulse by the addition of the velocity of the wind to that of sound, on the one hand, nor to the retardation of the latter by the motion of the wind, on the other. The inadequacy of this explanation must be evident when we reflect that sound moves at the rate of 750 miles an hour, and therefore a wind of 7½ miles an hour would only increase its velocity one per cent.; whereas the actual increase in audibility produced by a wind of this intensity is in some instances several hundred per cent.

In this state of our knowledge, a suggestion of Professor Stokes, of Cambridge, England, which offered a plausible explanation of the action of the wind, became known to us, and was immediately adopted as a working hypothesis to direct investigations.

This suggestion, the importance of which appears to have escaped general recognition, is founded on the fact that the several strata into which a current of air may be divided do not move with the same velocity. The lower stratum is retarded by friction against the earth and by the various obstacles it meets with, the one immediately above by friction against the lower, and so on; hence the velocity increases from the ground upward—a conclusion established by abundant observation. Now, in perfectly still air, a sounding instrument, such as a bell, produces a series of concentric waves perfectly spherical; but in air in motion the difference of velocity above and below disturbs the spherical form of the sound-wave, giving it somewhat the character of an oblique ellipsoid, by tending to flatten it above—to the windward, and to increase its convexity above—to the leward; and since the direction of the sound is perpendicular to the sound-wave, against the wind it will be thrown upward above the head of the observer, and in the opposite direction downward toward the earth. A similar effect will be produced, but with some variations and perhaps greater intensity, by a wind above, opposite to that at the surface of the earth.

These propositions will be rendered plain by the following illustrations (Figures 1, 2, and 3), for which I am indebted to an article in the American Journal of Science, by William B. Taylor.

Fig. 1.



In these, Figure 1 represents the effect of a favorable wind in depressing the waves of sound, S being the signal-station and O the point of observation. The wind blowing from W to E, as the spheroidal faces of the sonorous waves become more pressed forward by the greater velocity of the wind above, assuming it to be retarded at the surface by friction, and the direction of the acoustic beam being constantly normal to the wave-surfaces, the lines of direction of the sound will gradually be bent downward and reach the ear of the observer with an accumulated effect at the point O.

Fig. 2.

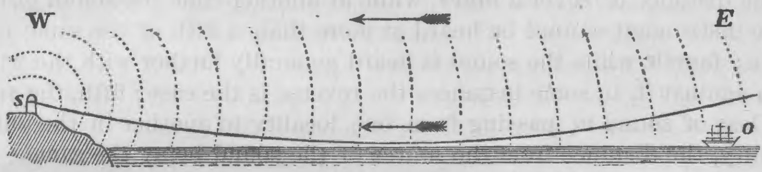


Figure 2 represents the ordinary effect of an opposing wind blowing from E to W against the sound; the wave-faces being more resisted above than below, assuming as before a retardation at the surface, the sound-beams are curved upward, and the lowest ray that would reach, in still air, the distant observer at O, is gradually so tilted up that it passes above the ear of the listener, leaving him in an acoustic shadow.

Fig. 3.

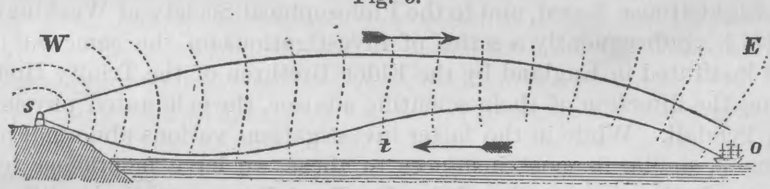


Figure 3 represents the disturbing effect of two winds, the lower in opposition to the sound at the surface, and the upper with it. In this case the principal effect will be a depression of the sound-beam, similar to that shown in Figure 1, but more strongly marked, as the difference of motion will be greater as we ascend. Attending this action, says Mr. Taylor, there will probably be some lagging of the lower stratum by reason of the surface-friction, the tendency of which will be to distort the lower part of the sound-waves, giving them a reverse or serpentine curvature. In this case the upper ray of sound would only have a single curvature, similar to that shown in Figure 1, while the lower rays would be represented by the lower line S O, rendering the sound less audible at an intermediate point, *t*, than at the more distant station O. This hypothetical case of compound refraction offers a plausible explanation of the paradox of a nearer sound being diminished in power by the wind which increases the effect of a more distant one.

In these figures and all the succeeding ones the direction of the wind is indicated by arrows.

The hypothesis we have adopted in connection with the fact of the lateral spread of sound gives a simple explanation of various abnormal phenomena of sound such as has been observed in the previous investigations, and of which the following are examples: First, the audibility of a sound at a distance, and its inaudibility nearer the source of sound; second, the inaudibility of a sound at a given distance in one direction; while a lesser sound is heard at the same distance in an opposite direction; third, the audibility of the sound of an instrument at one time at the distance of several miles, while at another time the sound of the same instrument cannot be heard at more than a fifth of the same distance; fourth, while the sound is heard generally farther with the wind than against it, in some instances the reverse is the case; fifth, the sudden loss of sound in passing from one locality to another in the same vicinity, the distance from the source of the sound being the same.

The first four of these phenomena find a ready explanation in the hypothesis adopted by supposing an increase or diminution in the relative velocity of the currents of wind in the upper or lower strata of air. The fifth is explained by the interposition of an obstacle which casts, as it were, a sound-shadow, disappearing at a given distance by the divergence of the rays on each side of the obstacle into what would be an optical shadow.

Accounts of these investigations were presented from time to time to the Light-House Board, and to the Philosophical Society of Washington in 1872. Subsequently a series of investigations on the same subject was instituted in England by the Elder Brethren of the Trinity House, under the direction of their scientific adviser, the celebrated physicist, Dr. Tyndall. While in the latter investigations various abnormal phenomena, similar in most instances to those we have mentioned, were observed, they were referred by Dr. Tyndall to an entirely different cause, viz, to the existence of acoustic clouds, consisting of portions of the atmosphere in a flocculent or mottled condition, due to the unequal distribution of heat and moisture, which, absorbing and reflecting the sound, produce an atmosphere of acoustic opacity. While we do not deny the possible existence of such a condition of the atmosphere, we think it insufficient to account for all the phenomena in question, and believe that a more general and efficient cause is that of the *wind*, in accordance with the hypothesis of Professor Stokes.

We regret to differ in opinion from Dr. Tyndall, and have published our dissent from his views in no spirit of captious criticism or desire to undervalue the results he has obtained, some of which are highly important. Our only object in our remarks and in our investigations is the establishment of truth.

The determination of the question as to the cause of the abnormal phenomena of sound we have mentioned, and the discovery of new phenomena, are not mere matters of abstract scientific interest, but are of great practical importance, involving the security of life and property, since they include the knowledge necessary to the proper placing of fog-signals, and the instruction of mariners in the manner of using them.

The hypothesis we have adopted, that of the change of direction of sound by the unequal action of the wind upon the sound-waves, is founded on well-established mechanical principles, and offers a ready explanation of facts otherwise inexplicable. It is also a fruitful source from which to deduce new consequences to be verified or disproved by direct experiment. It would however ill become the spirit of true science to assert that this hypothesis is sufficient to explain all the facts which may be discovered in regard to sound in its application to fog-signals, or to rest satisfied with the idea that no other expression of a general principle is necessary. An investigation however to be fruitful in results, as a general rule, must be guided by *a priori* conceptions. Hap-hazard experiments and observations may lead to the discovery of isolated facts, but rarely to the establishment of scientific principles. There is danger however in the use of hypotheses, particularly by those inexperienced in scientific investigations, that the value of certain results may be overestimated, while to others is assigned less weight than really belongs to them. This tendency must be guarded against. The condition of the experiment must be faithfully narrated, and a scrupulously truthful account of the results given. While we have used the hypothesis above mentioned in the following investigations as something more than an antecedent probability, we have not excluded observations which may militate against it, and we hold ourselves ready to admit the application of other principles, or to modify our conception of those we have adopted, when new facts are discovered which warrant such changes. But we require positive evidence, and cannot adopt any conclusions which we think are not based upon a logical correlation of facts.

The investigations described in the following account, though simple in their conception, have been difficult and laborious in their execution. To be of the greatest practical value they were required to be made on the ocean, under the conditions in which the results are to be applied to the use of the mariner, and therefore they could only be conducted by means of steam-vessels of sufficient power to withstand the force of rough seas, and at times when these vessels could be spared from other duty. They also required a number of intelligent assistants skilled in observation and faithful in recording results.

Observations in August, 1875, at Block Island.

The party engaged in these investigations consisted of the chairman of the Light-House Board; General Woodruff, U. S. A., engineer third light-house district; Dr. James C. Welling, president of Columbian University, Washington, D. C.; Mr. T. Brown, of New York, patentee of the siren; Mr. Edw. Woodruff, assistant superintendent of construction; and Captain Keeney, commander of the light-house steamer Mistletoe.

They arrived at Block Island on the afternoon of the 4th of August, 1875. This place was chosen as the site of the experiments, first, on account of its insular position, being as it were in the prolongation of the axis of Long Island, distant fifteen miles from the most easterly part of the latter, and entirely exposed to the winds and waves of the Atlantic Ocean; and, secondly, because there are on Block Island two light-houses, one of which is of the first order, and connected with it are two fog-signals, one of them with the latest improvements. (See Fig. 4.)

Observations in regard to the Aerial Echo.

This phenomenon has been frequently observed in the researches of the Light-House Board, in case of powerful sounds from the siren and from the fog-trumpet.* It consists of a distinct reflection of sound as if from a point near the horizon in the prolongation of the axis of the trumpet. The question of the origin of this echo has an important bearing, according to Dr. Tyndall, on the explanation of the abnormal phenomena of sound we have mentioned. He refers it to the non-homogeneous condition of portions of the air, which reflect back the waves of sound in accordance with the analogy of the reflection of light at the common surface of two media of different densities. We have adopted, as a provisional hypothesis, that it is due to the reflection from the waves and the larger undulations of the surface of the ocean, in connection with the divergency of beams of powerful sounds. To bring these hypotheses to the test of a crucial experiment, arrangements were made, under the direction of Mr. Brown, to change the direction of the axis of one of the sirens from the horizontal to the vertical position.

The first observations were made August 5, with the siren in its usual horizontal position, while the air was so charged with fog as to render the sound of the instrument necessary for the guidance of the mariner, the image of the sun being obscured and the land invisible from the sea. Under these conditions an echo was heard when the pressure of the steam reached 50 pounds per square inch. The reflection in this case, as usual, was from a point in the sea-horizon in the prolongation of the axis of the trumpet. It was not, however, heard more distinctly when standing near the origin of the sound than at several hundred feet on either side of it. The interval between the cessation of the original sound and the commencement of the echo was not as marked as in some previous observations, not being more than four or five seconds. The

* The same phenomenon is mentioned by Froissart in his account of the embarkation of the expedition of the French and English to the coast of Africa to assist the Genoese against the pirates in 1390. "It was a beautiful sight," says the chronicler, "to view this fleet, with the emblazoned banners of the different lords fluttering in the wind, and to hear the minstrels and other musicians sounding their pipes, clarions, and trumpets, whose sounds were re-echoed back by the sea." (See Illustrations of Froissart by H. N. Humphrey, Plate IV.)

duration of the echo was on the average about eight seconds, beginning with the time of its first perception, and not with the cessation of the sound of the trumpet. General Woodruff and Doctor Welling both noted the peculiar character of the echo, which was that of a series of reflections varying in intensity from a maximum, near the beginning, and gradually dying away. The wind was nearly at right angles to the axis of the trumpet and also to that of the crests of the swell of the ocean, which was rolling in from the effects of a commotion without. The barometer at 12 M. indicated 30.2 inches; the dry-bulb thermometer 73° F. the wet-bulb 70° F. indicating a remarkable degree of aqueous saturation. During the whole day the air in all the region around Block Island was undoubtedly in a homogeneous condition.

August 6.—On this day the weather was nearly the same. The fog-signal on the 5th instant was kept in operation for the use of the mariner nineteen hours, and on this day it was blown twenty hours continuously. The barometer marked 30.20 inches; the thermometer 70° F.; the fog not as equally distributed as on the preceding day; the north end of the island, distant four miles, being distinctly visible. The wind was S. W. to S., making an angle of about 60° with the axis of the fog-trumpet. The echo continued to be heard distinctly with a sound varying in intensity, but was not as loud as we have heard it on certain occasions in previous years.

During this and the preceding day, workmen were employed under Mr. Brown in inserting a flexible India-rubber tube, two inches in diameter, between the revolving plate of the siren and the smaller end of the trumpet, so that it might be brought into a vertical position. This work, though apparently simple, was difficult in execution, since it involved the necessity of strong supports for the cast-iron trumpet, which in itself weighed eight hundred pounds, and also of a union of the parts of sufficient strength to resist the pressure of the steam at fifty pounds to the square inch.

August 7.—Wind from the S. S. W. Fog continued; the workmen had not as yet completed the attachment.

August 9.—Barometer 30.30 inches at 12 M. Dry-bulb thermometer 74° F.; wet bulb 71°.5. Wind S. S. W. Fog dense along the south coast, but light over all the northern portion of the island. The echo was heard all day, not very loudly, but distinctly. Siren still horizontal, the arrangement for elevating it not having been, at 10 a. m., completed. Experiments were made on the reciprocal sounds of the whistles from two steamers, the results to be given hereafter. At 5 P. M. the adjustment of the flexible tube to the smaller end of the trumpet was finished, which, giving an additional length to the instrument of about 5 feet, threw it out of unison with the siren proper. To restore this unison the speed of revolution of the perforated plate was diminished, and after this the trumpet, still being horizontal, was sounded. An echo similar in character to those which had been observed on the preceding day, and the earlier part of the same day, was produced.

August 10.—Barometer 30.10 inches. Dry bulb 74°; wet bulb 69° F. Wind W. S. W.; atmosphere hazy. Observations first made with the trumpet horizontal. Echo as that of preceding days, distinct but not very loud, and coming principally from the portion of the horizon in the direction of the axis of the trumpet. The position of the trumpet was then changed, its axis being turned to the zenith in order to make what was thought might be a crucial experiment. When the trumpet was now sounded a much louder echo was produced than that which was heard with the axis of the trumpet horizontal, and it appeared to encircle the whole horizon; but though special attention was directed to the point by all the party present, no reverberation was heard from the zenith. The echo appeared however to be more regular and prolonged from the ocean portion of the horizon than from that of the land.

In this experiment, while there was no reflection from the zenith in which the sonorous impulse was strongest, there must have been reverberations from the surface of the land and the ocean. This will be evident when we consider the great divergency of sound by which sonorous waves from a vertical trumpet are thrown down to the plane of the horizon on every side, some of which, meeting oblique surfaces, must be reflected back to the ear of the observer near the source of the sound. This inference will be more evident when it is recollected that the reflected rays of sound diverge as well as those of the original impulse. Hence reflection from the surface of the sea is a true cause of the echo, but whether it be a sufficient one may require further investigation. For this explanation it is not necessary that the sea should be covered with crested waves; a similar effect would take place were the surface perfectly smooth but in the form of wide swells, which in places exposed to an open sea are scarcely ever absent. Moreover, the increased loudness of the echo is a fact in accordance with the same view.

The observations were repeated with the same effect on succeeding days, until this class of experiments was ended by the bursting of the India-rubber tube. Had a distinct echo been heard from the zenith, the result would have been decidedly in favor of the hypothesis of a reflection from the air; but as this was not the case the question still remained undetermined, especially since the atmosphere during these experiments was evidently in a homogeneous condition. We do not agree however in the position taken in the report of the Trinity Board, that on the origin of this echo depends the whole solution of the problem as to the efficient cause of the abnormal phenomena of sound. The ingenious experimental illustrations of the reflection of sound from a flame or heated air, establish clearly the possibility of such reflection; but it must be remembered they were made under exaggerated conditions, the atmosphere being in a state of extreme rarefaction in a limited space, and the sound of a feeble character, while the phenomena in nature are produced with a comparatively small difference of temperature and with powerful sounds.

Experiments at Block Island

RELATIVE TO THE EFFECT OF ELEVATION ON AUDIBILITY.

For this investigation the first-order light-house at Block Island offered peculiar facilities. It is situated near the edge of a perpendicular bluff, 152 feet above the sea. The tower being 52 feet above the base, gives a total height to the focal plane of the lens of 204 feet, on the level of which the ear of the observer could be placed.

The first and second experiments of this class were made on the 10th of August, with two light-house steamers, the Putnam and the Mistletoe, moving simultaneously in opposite directions. The barometer indicated 30.10 inches of atmospheric pressure; the dry-bulb thermometer indicating 74° F., and the wet-bulb 69°. The wind at the time of the experiments was from the west, and of a velocity of seven miles per hour. The vessels started from the point C, Fig. 4, opposite the light-house, A, about one mile distant, a position as near the shore as it was considered safe to venture. The Putnam steamed with the wind, the Mistletoe steamed against the wind, each blowing its whistle every half minute. The duration of the sound was noted at the top of the tower and at the level of the sea, Mr. Brown being the observer at the latter station, while the chairman of the board, with an assistant, observed at the former. On comparing notes, the watches having been previously set to the same time, it was found—

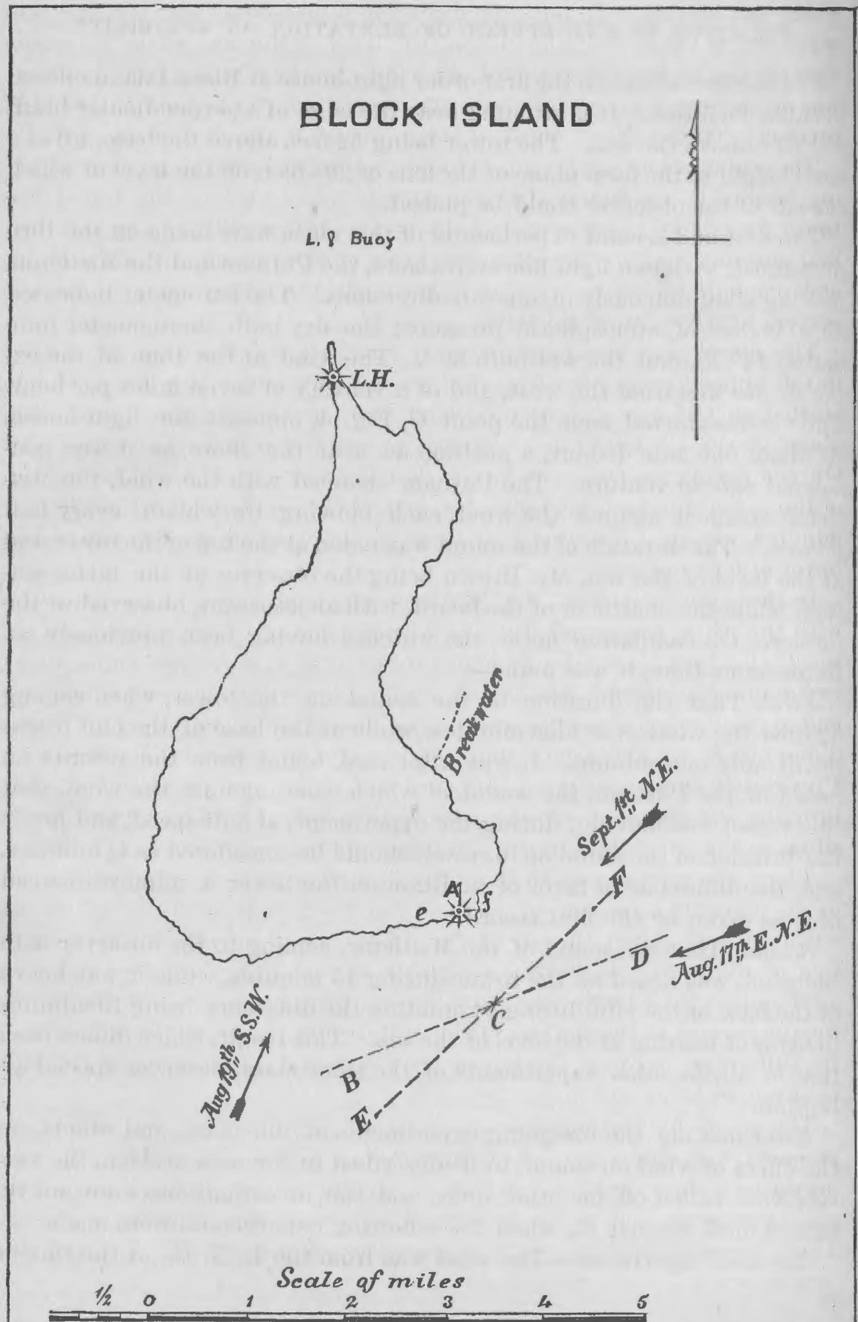
First. That the duration of the sound on the tower, when coming against the wind, was nine minutes, while at the base of the cliff it was heard only one minute. It was afterward found from the records on board of the Putnam, the sound of which came against the wind, that this vessel was moving, during the experiment, at half-speed, and hence the duration of the sound on the tower should be considered as 4½ minutes, and the difference in favor of audition on the tower 4 minutes instead of 8, as given by the first record.

Second. That the sound of the Mistletoe, coming to the observer with the wind, was heard on the tower during 15 minutes, while it was heard at the base of the cliff during 34 minutes, the difference being 19 minutes in favor of hearing at the level of the sea. This result, which differs from that of all the other experiments of the same class, deserves special attention.

After making the foregoing experiments of this class, and others, on the effect of wind on sound, to be described in the next section, the vessels were called off for other duty, and the investigations were not resumed until August 17, when the following experiments were made:

The third experiment.—The wind was from the E. N. E., at the rate of about five miles per hour at the surface, and a greater velocity at the height of the tower. Barometer, 30.25 ins.; thermometer, 72°.

Fig. 4.



In this and the subsequent experiments of the same day but one steamer—the Mistletoe—was employed. It started at 10:30 A. M. from the point C, Fig. 4, at the foot of the cliff, and steamed W. S. W. along C B for about 12 minutes, or a distance of two miles, blowing the whistle every half-minute. To note the duration of the sound, Dr. Welling was stationed at the foot of the cliff, at the level of the sea, while the chairman of the Light-House Board, with an assistant who acted as clerk, was on the upper gallery of the tower, the ears of the latter being almost precisely 200 feet above those of the observer at the foot of the cliff.

The watches having been previously set to the same time, on comparing results it was found that the whistle was heard at the top of the tower for twelve minutes and at the bottom of the cliff for five and one-half minutes, making the difference in favor of audition on the tower six and one-half minutes. In this experiment the sound came to the observers nearly against the wind.

The *fourth experiment* consisted in directing the Mistletoe to proceed in the opposite direction from the same point, along the line C D. It started at 11:5 A. M. the breeze being light at the time, and proceeded about two and one-half miles before the sound was lost to the observers. On comparing notes it was found that the sound was heard at the top of the tower during fifteen minutes, and at the level of the sea for eleven minutes, giving a difference in favor of the hearing on the top of the tower of four minutes.

In the *fifth experiment*, the Mistletoe steamed again in the direction with the wind, the sound from its whistle coming to the ears of the observers against the wind. Starting about 11:45 A. M. and steaming about two miles, the sound was heard on the tower during twelve minutes and at the foot of the cliff during five and one-half minutes, making a difference of six and a half minutes in favor of audition on the tower. Previous to this experiment the wind had veered one point to the west, bringing the direction of the sound to the observers in less direct opposition to the wind than in the last experiment.

The sixth experiment.—In this case the steamer was directed to proceed in the opposite direction, or against the wind, so that the sound of the whistle would reach the ear of the observers in the same direction as that of the wind. It started at 12:19 P. M. and proceeded two and one-sixth miles; the whistle was heard during thirteen minutes on the top of the tower, and at the bottom of the cliff during precisely the same time, the difference between the top of the tower and the bottom of the cliff in this case being nothing.

The vessel having again been called off on other duty the *seventh experiment* was made the 1st of September. On this day the wind was northeast; the velocity at the top of the tower was thirteen and a half miles per hour, and at the bottom of the tower eleven miles per hour. The barometer indicated 30.20 inches pressure, the dry bulb 72°, and the wet bulb 67½°.

The theoretical conditions for exhibiting the effect of height on audition in this experiment were much more favorable than any of the preceding. First, the velocity of the wind was greater; second, the difference between the velocities at top and bottom of the tower was well marked, and the direction of the wind was more favorable for direct opposition to the sound as it came to the ear of the observer. In this case General Woodruff was the observer at the bottom of the cliff, while the chairman of the Light-House Board and his assistant, with several visitors, were at the top of the tower.

The steamer started at 10:58 A. M. and proceeded during eight minutes, or a mile and one-third, when the sound was lost at the top of the tower. In this case, though the sound was heard for eight minutes from the top of the tower, and the first five blasts marked on the notes as quite loud, it was not heard at all at the bottom of the cliff at least a hundred yards nearer the source of the sound.

This result, which interested and surprised a number of intelligent visitors, who were in the tower at the time, strikingly illustrates the effect of elevation on the audibility of sound moving against the wind. The result was so important that it was thought advisable to immediately repeat the experiment under the same conditions.

In the *eighth experiment*, the Mistletoe was again directed to proceed, in the direction of the wind, along the line it had previously traversed. It started at 11:25 A. M., and proceeded during six minutes, or one mile, when the sound was lost at the top of the tower. In this case, the first blast of the whistle was feebly heard at the base of the cliff, but no other, while thirteen blasts were heard at the top of the tower, of which the first six were marked as loud.

That this remarkable effect was not produced by an acoustic cloud or a flocculent atmosphere is evident from the experiment which immediately succeeded.

The ninth experiment.—In this trial, the Mistletoe was directed to proceed against the wind, so that the sound of its whistle should come to the ears of the observers with the wind. It started at 11:48 A. M., and proceeded during sixteen minutes, or two and two-thirds miles, when the sound of its whistle was lost to the observers on the top of the tower. In this case the sound of the whistle became audible at the bottom of the cliff as soon as the position of the vessel became such as to bring the sound to the observers approximately with the wind, and continued to be audible during fifteen minutes, or within one minute as long as the sound was heard at the top of the tower.

It may be mentioned as an interesting fact, that an assistant who was observing the sound with General Woodruff at the foot of the cliff, when the sound could not be heard at the level of the sea, in the sixth experiment perceived it distinctly by ascending the side of the cliff to a height of twenty-five or thirty feet.

All the conditions and results of these experiments are strikingly in conformity with the theory of the refraction of sound which we have previously explained.

The following recapitulation of the results of the foregoing experiments will exhibit their correspondence with the general theory:

Sound heard coming against the wind.

Experiments.	Duration at the top of the tower.	Duration at the base of the cliff.	Difference in favor of audition on the tower.
First	4½ minutes	½ minute	4 minutes.
Third	12 minutes	5½ minutes	6½ minutes.
Fifth	12 minutes	5½ minutes	6½ minutes.
Seventh	8 minutes	Not heard	8 minutes.
Eighth	6 minutes	First blast heard, but no other, ½ minute after starting.	5½ minutes.
	42½ minutes	12 minutes.	30½ minutes.
Average	8½ minutes	2.4 minutes	6.1 minutes.

Sound heard coming with the wind.

Experiments.	Duration at the top of the tower.	Duration at the base of the cliff.	Difference in favor of audition at base of cliff.
Second	15 minutes	34 minutes	19 minutes.
Fourth	15 minutes	11 minutes	— 4 minutes.
Sixth	13 minutes	13 minutes	0 minutes.
Ninth	16 minutes	15 minutes	— 1 minute.
	59 minutes	73 minutes	14 minutes.
Average	14¾ minutes	18¼ minutes	3½ minutes.

From the first of the foregoing tables it appears that the elevation of the observer has a marked effect on the audition of sound moving against the wind while, from the second, with one important exception, it has very little, if any, effect on sound moving with the wind. Another experiment relative to the same class of phenomena was made on the 19th of August (see Fig. 4), the wind being S. S. W. Two observers, General Woodruff and Dr. Welling, starting from the bottom of the cliff immediately below the light-house, went along the beach, the one in the direction A *f*, and the other in direction A *e*. General Woodruff found that the sound of the siren was distinctly heard all the way to the breakwater, and was so loud that it probably could have been heard for several miles in that direction. Dr. Welling, on the contrary, entirely lost the sound within a quarter of a mile of the light-house. This result is readily explained as a case of lateral refraction; the wind was in the direction traversed by General Woodruff, and contrary to that pursued by Dr. Welling. In the one case the wind, retarded by the surface of the cliff, moved with less velocity than it did farther out, and consequently the sound was thrown against the face of the cliff, and on the ear of the observer, and in the other thrown from it, thus leaving, as it were, a vacuum of sound. The effect in the case was very striking, since the siren was pointed toward the zenith, and the sound in still air could have been heard for miles in every direction.

Investigations at Block Island

IN REGARD TO THE EFFECT OF WIND ON AUDIBILITY.

These were made by the aid of two steamers. Captain Walker, naval secretary of the board, having completed a series of inspections in the Third District, sent the steamer Putnam, under Captain Fields, to aid the Mistletoe in the investigations. They were commenced on the 9th of August, at 12 o'clock. The wind was S. S. W. with a velocity of $7\frac{1}{4}$ miles per hour. Barometer, 30.3 inches; thermometer, dry bulb, 74° F. wet bulb, $71\frac{1}{2}$° F.

The two steamers started from a buoy near the north end of the island, the one steaming against the wind, and the other with it, each blowing its whistle every minute. The distance travelled by each steamer was estimated by the running time, which, from previous observations, was found to be ten miles per hour. Each vessel was furnished with a whistle of the same size, of 6 inches diameter, actuated by the same pressure of 20 pounds of steam, and which, by previous comparison, had been found to give sound at this pressure of the same penetrating power. The observations on the Mistletoe were made by General Woodruff, and on the Putnam by Dr. Welling, each assisted by the officers of the respective vessels. The two steamers proceeded to buoy off the north end of the island, in which position the wind was unobstructed by the land—a low beach. Indeed, the island being entirely destitute of trees, and consisting of a rolling surface, the wind had full sweep over it in every direction.

First experiment.—The Putnam went against the wind and the Mistletoe in the opposite direction. The Putnam lost the sound of the whistle of the Mistletoe in two minutes and stopped, but continued to blow the whistle. The Mistletoe continued on her course and heard the Putnam's whistle for twenty minutes in all. During the first two minutes both vessels were in motion, and therefore the space through which the sound was heard moving against the wind would be represented by 4, while the space through which the sound was heard moving with the wind would be represented by $20 + 2 = (22)$, the ratio being $1 : 5\frac{1}{2}$.

Second experiment.—In this the Putnam went with the wind and the Mistletoe in the opposite direction. The Mistletoe lost the sound of the Putnam's whistle in two minutes. The Putnam then stopped and remained at rest; while the Mistletoe continued on her course until the Putnam lost sound of her whistle, twenty-six minutes later. As both steamers were separating during the first two minutes with equal speed, the distance travelled by the sound heard moving against the wind is represented by 4, while the distance of the sound heard with the wind is represented by $26 + 2 = 28$, the ratio being 1 : 7. It should be mentioned, however, that the notes in this experiment are defective and somewhat discrepant.

Third experiment.—The Putnam went against the wind, the Mistletoe in the opposite direction. The Putnam lost the sound of the whistle of the Mistletoe in two minutes, while the Mistletoe continued to hear the whistle of the Putnam ten minutes longer. Owing to a misunderstanding, one of the steamers stopped for two minutes and then resumed its course. As both steamers were separating during the first two minutes with equal speed, the distance of the sound heard moving against the wind is represented by 4, while the sound heard with the wind through a space denoted by $2 \times 10 + 4 - 2 = 22$, the ratio being 1 : $5\frac{1}{2}$.

Fourth experiment.—The vessels again changed directions, the Putnam going with the wind, and the Mistletoe in the opposite direction. The Mistletoe lost the sound in two minutes, and the Putnam nine minutes later. As each steamer was moving from the other at the same rate, the distance of the sound heard moving against the wind would be represented by 4, while the distance of the sound moving with the wind would be represented by $9 \times 2 + 4 = 22$, the ratio being again 1 : $5\frac{1}{2}$.

Fifth experiment.—This experiment was made August 10, by the same vessels and same observers, wind W. S. W., of about the same intensity as on previous days; barometer, 30.1 ins.; dry bulb, 74° F. wet bulb, 69°. The Putnam steamed against the wind, and the Mistletoe in the opposite direction. The Putnam lost the sound in two minutes, and the Mistletoe nine minutes later. The two vessels moving apart with equal velocity, the space traversed by the sound moving against the wind was represented by 4, while that in the opposite direction was represented by 22, viz, $9 \times 2 + 4 = 22$.

Sixth experiment.—The vessels were next separated in a direction at right angles to the wind, when each reciprocally lost the sound of the other on an average of six minutes, giving a distance travelled by the sound, while audible, of twelve spaces.

Seventh experiment.—The vessels were next directed along an intermediate course between the direction of the wind and a line at right angles to it, with the following results: The Mistletoe, against the wind, lost the sound in about two minutes, while the Putnam heard the sound seven minutes longer. As in the previous case, the two vessels moving apart with equal velocity would in two minutes be separated by a space represented by 4, which would indicate the audibility of the sound moving against the wind, and for the same reason the other vessel, hearing the sound seven minutes longer, would have the additional space represented by 14, and adding to this four spaces, we have 18 to represent the audibility of the sound in the direction approximating that of the wind.

The following table exhibits at one view the results of the foregoing experiments, which relate to sound moving against the wind, and with the wind, reduced to miles.

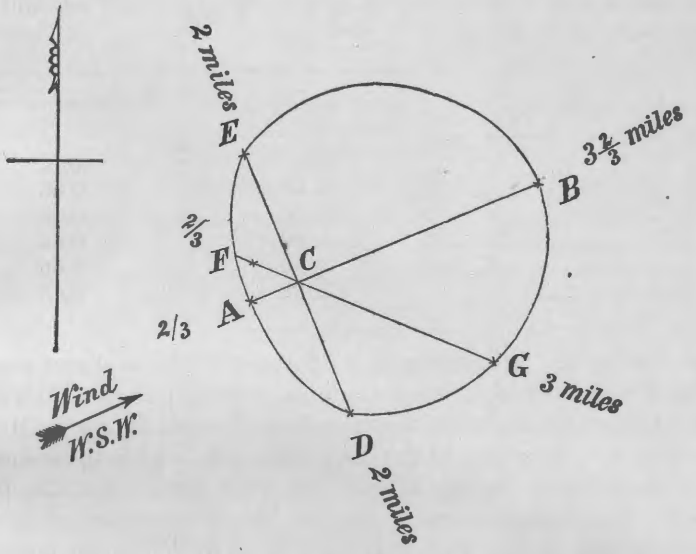
Experiment.	Sound with the wind.	Sound against wind.
	Miles.	*Miles.*
1	3. 66	0.66
2	4. 66	0.66
3	3. 66	0.66
4	3. 66	0.66
5	3. 66	0.66

These results are in accordance with those of all the direct observations which had previously been made on sound in regard to wind by the Light-House Board, with the exception of those at Sandy Hook in September, 1874, as given in the last report, in which the sound was heard from a steamer farther against the wind than in the direction of the wind. This anomaly was explained by the existence of an upper current of air, moving in an opposite direction to that at the surface, in accordance with the hypothesis of the refraction of sound.

It will be observed that four of the experiments give exactly the same distances to represent the audibility of sound with and against the wind. This coincidence was not observed until after the notes were collated for discussion, and, if not accidental, was due to the equal velocity of the wind and the general conditions of the atmosphere on the two days.

To give a definite idea of these relations we have plotted the results obtained on August 10, in Fig. 5, converting the distances into miles and referring them to a common center, and tracing through the several extremities of the lines representing the distances a continuous line, which may be designated as the curve of audibility. C being the center to which the sounds are referred, C A represents the distance at which the sound was heard against the wind, and C B in the direction of the wind, while C E and C D represent the distance at right angles to the wind, and F C and C G the distances respectively with and against the wind on an intermediate course.

FIG. 5.



The curve which is presented in the foregoing figure may be considered as that which represents the normal limit of audibility during the two days in which the experiments were made. The line D E divides the plane of the curve into two unequal portions, D A F E and D G B E, the former representing the audibility of sound moving against the wind, and the other the audibility of sound moving with the wind.

We can scarcely think that any other condition of the air than that of its motion could produce a result of this kind. It exhibits clearly the fact that sound is not heard as a general rule at right angles to the wind farther than with the wind, as has been asserted. In this case the ratio of the latter to the former is as 11 to 6, or nearly double.

The investigation of the relation of wind to the penetration of sound was renewed in a series of subsequent experiments, the results of which are to be given in a succeeding part of this report.

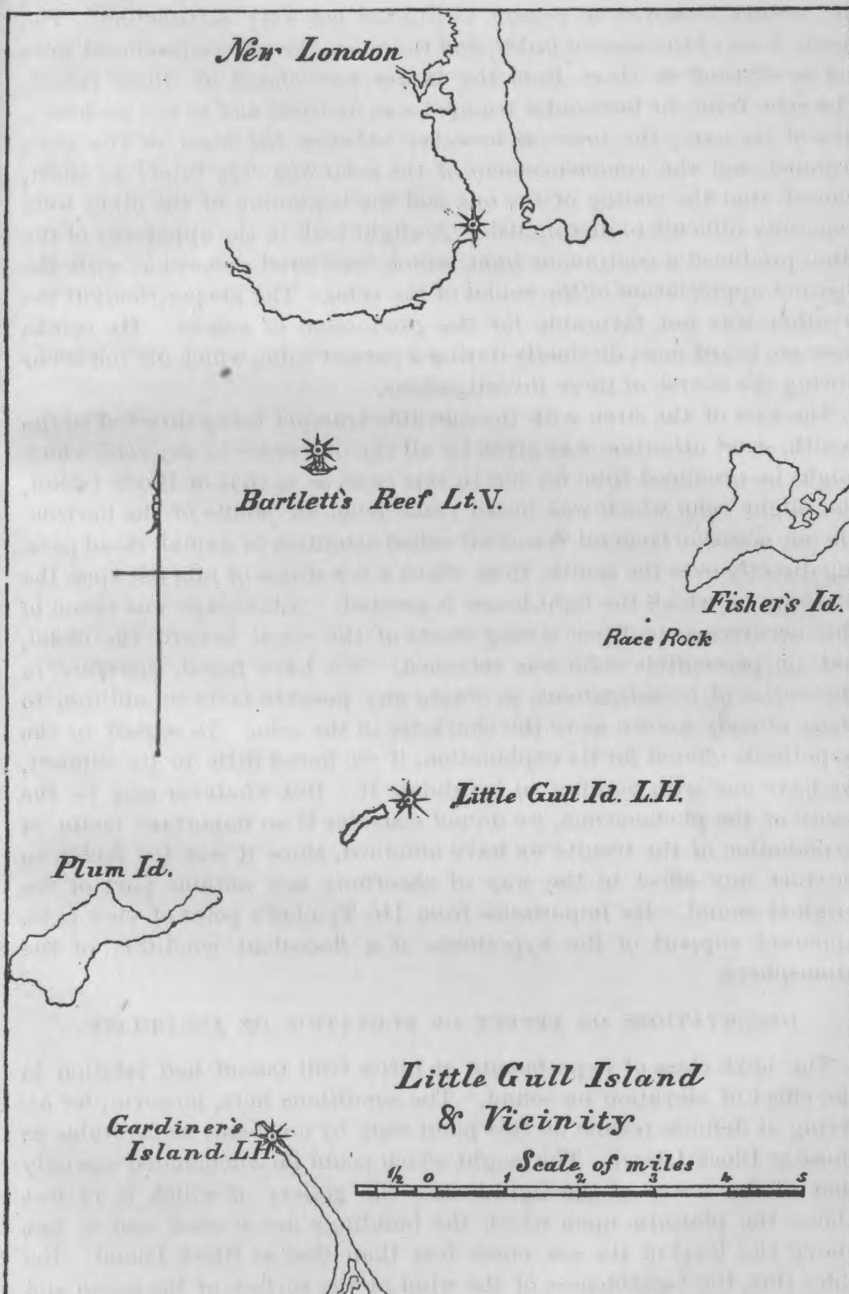
It should be observed, in comparing Fig. 5 with the subsequent figures representing the curve of audibility, that the arrow representing the direction of the wind points in the longest direction to the figure, whereas in other figures the pointing is in the opposite direction. The difference arises from the fact that in Fig. 5 the sound is supposed to radiate from the center, C, while in the others the sound converges to the center as a point of observation. The foregoing diagram and all that follow in this report were plotted by Mr. Edward Woodruff, assistant superintendent of construction of the third light-house district.

EXPERIMENTS AT LITTLE GULL ISLAND, SEPTEMBER, 1875.

The next series of experiments made during this season was at Little Gull Island, at the east end of Lond Island Sound. This location was chosen on account of its convenience of approach from the harbor of New London, seven miles distant, at which the light-house steamers of the third district usually remain when not engaged in active service, and also because there is a light-house on the island furnished with two sirens of the second order, and an extent of water on every side which would allow the vessels used in the experiments to proceed from the island as a center to a considerable distance in every direction. The island itself is a small protuberance above the water, merely sufficient in area to support a raised circular platform of about 100 feet in diameter, on which the light-house and other buildings are erected. The following sketch (Fig 6) will give an idea of the position of Gull Island relative to the main-land and the islands in the vicinity.

From this it will be seen that the position was not the most favorable for a stable condition of the atmosphere. As the heat of the sun increases during the first part of the day, the temperature of the land rises above that of the sea; and this excess of temperature produces upward currents of air, disturbing the general flow of wind both at the surface of the sea and at an elevation above. But although the locality was unfavorable for obtaining results tending to exhibit the effects of broad currents of wind flowing in one direction, it had the advantage of offering more varied phenomena than could otherwise have been exhibited. Before commencing the experiments, directions were given to attach a rotating iron neck to the trumpet of one of the sirens, in order that it might be directed to the zenith; while the other siren remained with its axis in a horizontal direction. The observers in these investigations consisted of the chairman of the board; General Woodruff, engineer third district; Porter Barnard, assistant superintendent of construction; Captain Keeney, and other officers of the Mistletoe; with an assistant who acted as one of the observers and recording clerk. The Mistletoe was daily employed, though on two occasions the Cactus, another of the light-house steamers, rendered assistance.

Fig. 6.


New London
Bartlett's Reef Lt.V.
Fisher's Id.
Race Rock
Little Gull Id. L.H.
Plum Id.
Little Gull Island
& Vicinity
Gardiner's
Island L.H.
Scale of miles
½ 0 1 2 3 4 5

OBSERVATIONS ON THE ECHO AT LITTLE GULL ISLAND.

The first observations to be mentioned are those relating to the echo; the results, however, in regard to this are not very satisfactory. The sirens were of the second order, and therefore the echoes produced were not as distinct as those from the larger instrument at Block Island. The echo from the horizontal trumpet was distinct, and in the prolongation of its axis; the interval however between the blast of the siren trumpet and the commencement of the echo was very brief; so short, indeed, that the ending of the one and the beginning of the other were generally difficult to distinguish. A slight leak in the apparatus of the siren produced a continuous hum, which interfered somewhat with the distinct appreciation of the sound of the echo. The keeper thought the weather was not favorable for the production of echoes. He thinks they are heard most distinctly during a perfect calm, which did not occur during the course of these investigations.

The axis of the siren with the movable trumpet being directed to the zenith, strict attention was given by all the observers to any echo which might be produced from it; but in this case, as in that at Block Island, the slight echo which was heard came from all points of the horizon. On one occasion General Woodruff called attention to a small cloud passing directly over the zenith, from which a few drops of rain fell upon the platform on which the light-house is erected. Advantage was taken of this occurrence to direct strong blasts of the siren toward the cloud, but no perceptible echo was returned. We have failed, therefore, in this series of investigations, to obtain any positive facts in addition to those already known as to the character of the echo. In regard to the hypothesis offered for its explanation, if we found little in its support, we have met with nothing to invalidate it. But whatever may be the cause of the phenomenon, we do not consider it an important factor in explanation of the results we have obtained, since it was too feeble to produce any effect in the way of absorbing any notable part of the original sound. Its importance from Dr. Tyndall's point of view is its apparent support of the hypothesis of a flocculent condition of the atmosphere.

OBSERVATIONS ON EFFECT OF ELEVATION ON AUDIBILITY.

The next class of experiments at Little Gull Island had relation to the effect of elevation on sound. The conditions here, however, for arriving at definite results on this point were by no means as favorable as those at Block Island. The height which could be commanded was only that of the tower of the light-house, the gallery of which is 74 feet above the platform upon which the buildings are erected, and 92 feet above the level of the sea, much less than that at Block Island. Besides this, the variableness of the wind at the surface of the ocean and at heights above was not favorable for the illustration of the point in question.

The theoretical conditions in order that the sound may be heard with greater distinctness at an elevation than below are, as we have said before, that the wind be moving with a greater velocity in a given direction at an elevation than at the surface of the earth, and that the difference in the velocities may be against the sound-wave, so that its upper part may be more retarded than the lower. In this case the direction of a beam of sound will be curved upward, leaving as it were a vacuum of sound beneath. The distance of the origin of sound, however, must not be too great relatively to the elevation of the observer; otherwise it will pass over his head, as well as over that of the observer at the surface of the earth. In most instances the sound was not continuous, but was interrupted—heard for a time, then lost; again becoming audible, it was heard until it finally became imperceptible. Besides this, it was difficult to determine when the sound ceased to be heard, since this depended on the sensibility of the ear and the greater or less attention of the observer at the time of the observation. To obviate these difficulties as well as the unfavorable condition of too great a distance of the origin of sound from the observer, it was concluded to adopt as the duration of the sound the elapsed time between its beginning and the period when it was first lost.

The observer on the tower was Mr. P. Barnard, while the one below was General Woodruff. From the records of the observations of these gentlemen the following tables are compiled, the first of which indicates the relative duration of sound on the top of the tower and at the bottom, the sound moving against the wind; the second, the same duration, the sound moving with the wind; and the third, the same with the sound at right angles to it.

TABLE 1.—*Sound against the wind.*

Date.	Heard at top of tower.		Heard at bottom.	
1875.	*min.*	*sec.*	*min.*	*sec.*
September 2	5	30	4	00
4	4	30	3	30
4	5	30	3	00
4	5	00	4	00
6	7	00	2	15
6	4	00	3	00
7	5	00	2	15
8	6	00	4	00
8	5	30	3	45
8	3	30	2	15
8	3	00	1	15
Mean	4	57	3	01

It appears from Table 1 that without a single exception the duration of the sound was greater at the top of the tower than at the bottom, although the difference in favor of the top of the tower in the several experiments is very variable. These results are in accordance with what was anticipated.

TABLE 2.—*Sound with the wind.*

Date.	Heard at top of tower.		Heard at foot of tower.	
	min.	*sec.*	*min.*	*sec.*
September 2	30	00	30	00
3	16	30	18	00
4	21	00	20	30
4	18	00	23	30
6	12	30	12	30
7	6	30	5	30
Mean	17	25	18	20

In these observations the duration of the sound at the bottom and top are nearly the same, from which we might infer that the elevation of the observer has little effect on the hearing of sound moving with the wind. Were it not for the result of the first experiment of this class at Block Island, we should not hesitate to adopt this as a general conclusion.

TABLE 3—*Sound heard nearly at right angles to the wind.*

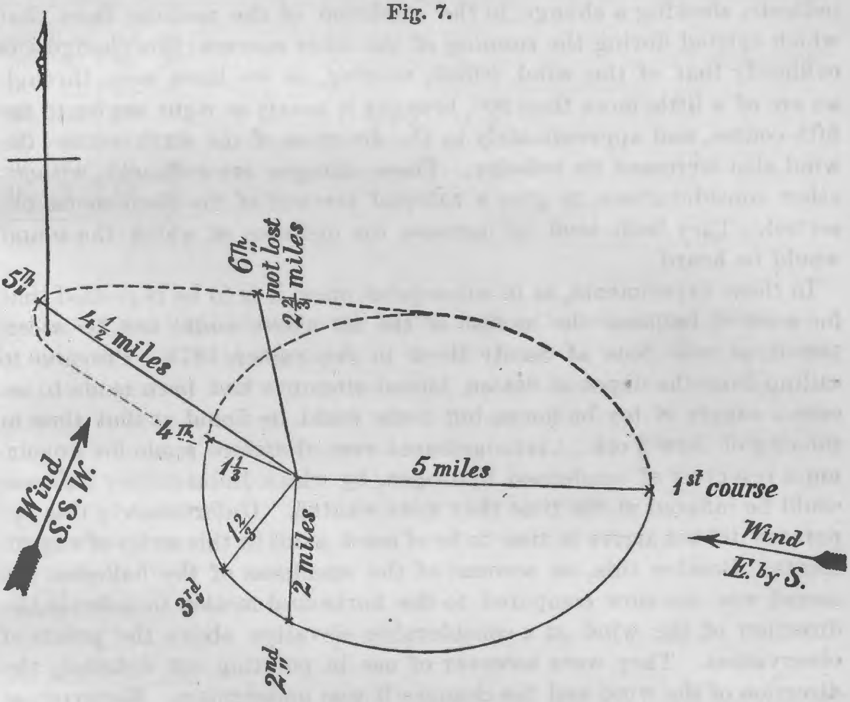
Date.	Heard at top of tower.		Heard at foot of tower.	
	min.	*sec.*	*min.*	*sec.*
September 2	6	00	4	00
2	6	45	10	00
2	25	00	23	00
2	16	30	4	00
3	21	00	19	15
3	16	00	14	30
3	23	30	16	45
4	19	30	17	30
6	6	30	5	30
7	5	00	6	45
7	12	00	12	30
8	4	15	3	15
8	9	30	5	00
Mean	13	12	10	55

From the result of this table it would appear that the sound can be heard moving at right angles to the wind better at an elevation that at the surface—a result not anticipated.

OBSERVATIONS ON THE EFFECT OF WIND ON SOUND.

This series was commenced on the 2d of September. Barometer, 30.3 inches; thermometer, dry-bulb, 70°.5 F. wet-bulb, 67°.5. Wind at the surface of sea was six miles per hour, and variable; at 3 p. m. the velocity was eight miles at the surface. (See Fig. 7.)

Fig. 7.



The experiments were made by means of the steamer Mistletoe, which proceeded from the light-house, as a center, in different directions, blowing the whistle every half-minute, and returning when, from a signal, the sound was lost; the time being noted by different observers, and the distance estimated by the position of the steamer in reference to known objects on the Coast-Survey chart, as well as by angles of azimuth and time of sailing. The steamer was directed to proceed, as indicated in Fig. 7, 1st, against the wind, so that the sound would come to the observers with the wind; 2d, at right angles to the wind; 3d, in an intermediate direction between the last course and the direction of the wind; 4th, approximately with the wind, so that the sound would come to the ears of the observers against the wind; 5th, in an intermediate direction; and, 6th, again at right angles to the wind. It was supposed that by this arrangement a symmetrical curve of sound would be obtained; and we think this would have been the case had the wind remained constant in direction. It did remain nearly the same during the time of describing the first, second, and third courses, and only slightly varied during the fourth; but previous to running the fifth and sixth courses the wind had changed to a direction nearly at right angles to its first course.

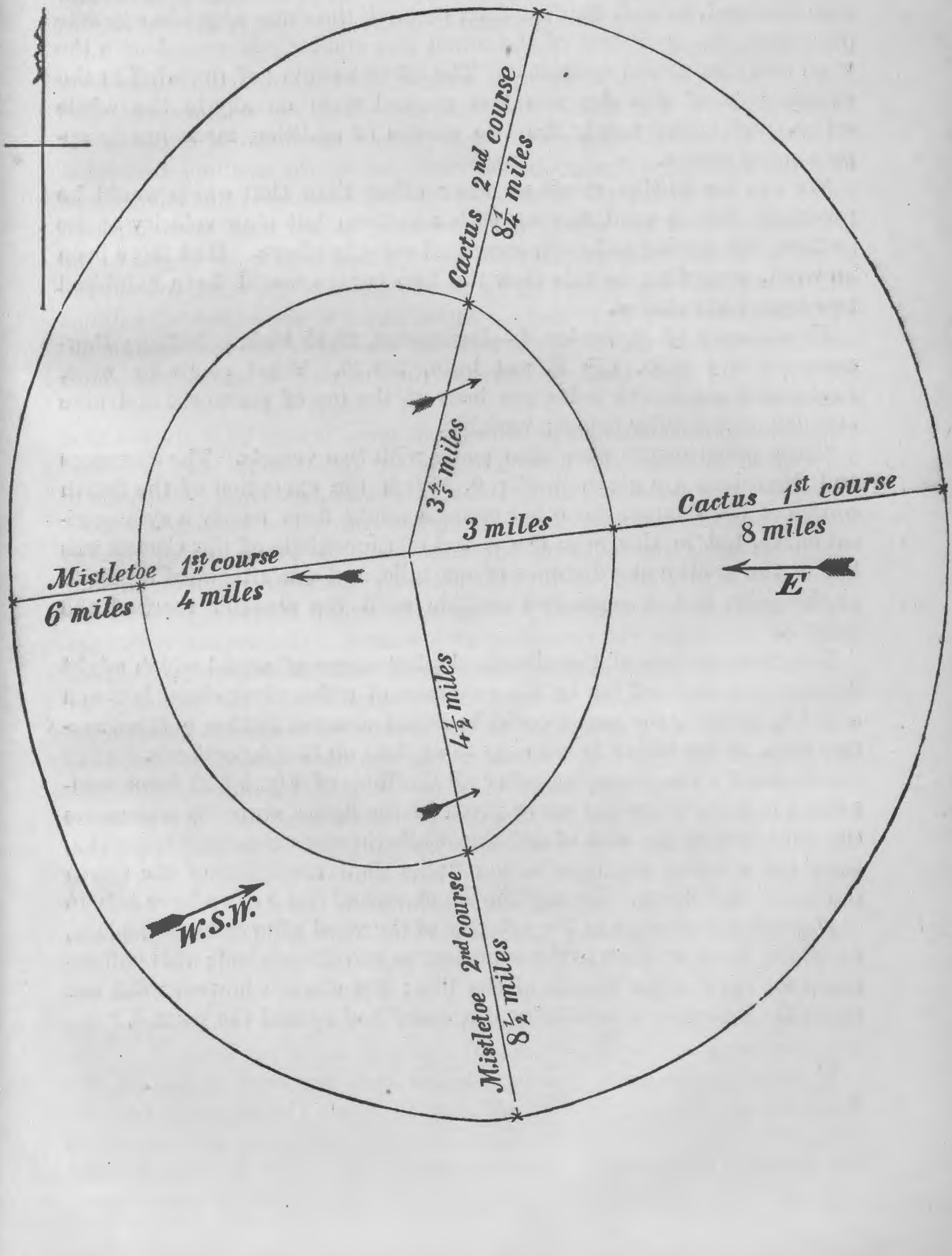
As is shown in Fig. 7, the first, second, third, and fourth courses form a normal curve of audition; the fifth and sixth courses, however, give discordant results, being much longer than a symmetrical curve would indicate, showing a change in the condition of the medium from that which existed during the running of the other courses; this change was evidently that of the wind, which, veering, as we have seen, through an arc of a little more than 90°, brought it nearly at right angles to the fifth course, and approximately in the direction of the sixth course; the wind also increased its velocity. These changes are sufficient, without other considerations, to give a rational account of the phenomena observed. They both tend to increase the distance at which the sound would be heard.

In these experiments, as in subsequent ones, it is to be regretted that for want of balloons the motion of the air above could not be ascertained, as was done at Sandy Hook in September, 1874. Previous to sailing from the depot at Staten Island attempts had been made to secure a supply of toy balloons, but none could be found at that time in the city of New York. Arrangements were therefore made for procuring a reservoir of condensed hydrogen, by which India-rubber balloons could be inflated at the time they were wanted. Unfortunately this apparatus did not arrive in time to be of much avail in this series of experiments. Besides this, on account of the smallness of the balloons, the ascent was too slow compared to the horizontal motion to indicate the direction of the wind at a considerable elevation above the points of observation. They were however of use in pointing out definitely the direction of the wind and the changes it was undergoing. Moreover, at the time of leaving New York we were only able to procure one anemometer, whereas we ought to have had a number, one for the top of the tower, one for the bottom, and one for each vessel.

Experiments of September 3.—Barometer, 30.02 inches; thermometer, dry bulb, 72°.5 F. wet bulb, 70°; wind from the east, but too slight to move the cups of the anemometer; it soon however spang up from the opposite direction, in which it continued during the remainder of the day, attaining a velocity of five and a quarter miles per hour.

In these experiments two light-house steamers were employed, the Mistletoe and Cactus, which enabled us to obtain the results in half the time, and thus to obviate the effect, in some degree, of any change in the direction of the wind. On this occasion the sound was noted at the light-house as it converged to a center from the whistle of each vessel,

Fig. 8.


Cactus 2nd course
8 1/4 miles
3 4/5 miles
Cactus 1st course
8 miles
3 miles
Mistletoe 1st course
4 miles
6 miles
E
4 1/2 miles
W.S.W.
Mistletoe 2nd course
8 1/2 miles

and also simultaneously by each vessel as it diverged from the vertical siren.

We were enabled, in this way, to produce two curves by a reverse process. These are plotted in Fig. 8, and exhibit a remarkable degree of similarity. The corresponding parts of the two curves, being in each case reversed, exhibit the fact that, through the same space in opposite directions, the audibility of the sound was similarly increased with the wind and diminished against it. The effect however of the wind in the experiments of this day was less marked than on any in the whole series, and consequently the two curves of audition more nearly approximate circles.

We can see in this result no other effect than that which would be produced from a wind flowing with a uniform but slow velocity at the surface, but having a slightly increased velocity above. Had there been no wind, according to this view the two curves would have exhibited two concentric circles.

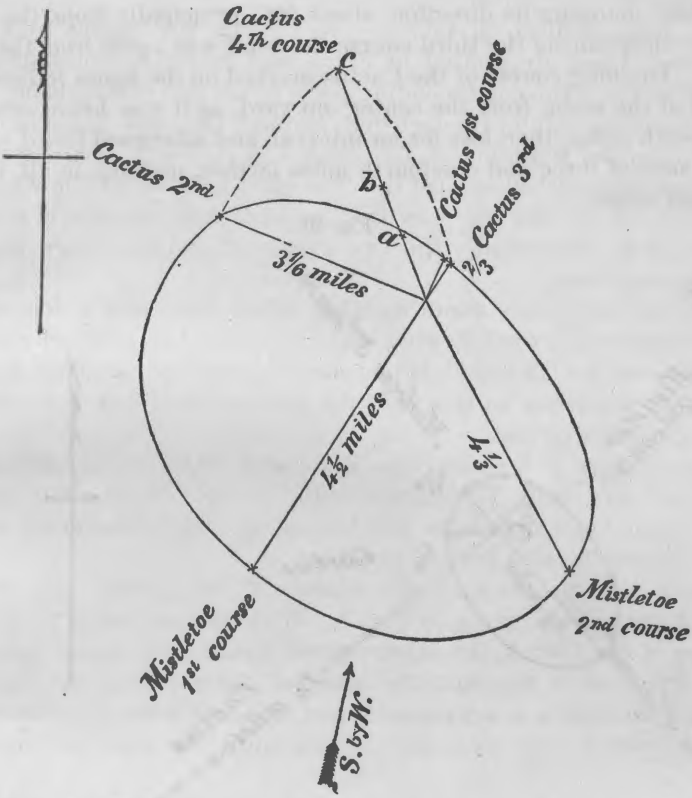
Experiments of September 4.—Barometer, 29.85 inches, falling; thermometer, dry bulb, 77° F. wet bulb, 73°.25. Wind south by west, twelve and one-fourth miles per hour at the top of the tower and nine and one-fourth miles below; variable.

These experiments were also made with two vessels. The distances and directions are given in Fig. 9. With the exception of the fourth course of the Cactus, the other courses would form nearly a symmetrical curve, but in this case the sound of the whistle of the Cactus was lost at the point *a* at a distance of one mile, and was afterward regained at the point *b*, and continued audible until the steamer reached the point *c*.

This presents one of the abnormal phenomena of sound which might in part be accounted for by the existence of a flocculent cloud between *a* and *b*, but why the sound could be heard so much farther in this direction than in the others is not easy to explain on that hypothesis.

The line *b c* was described after all the lines of Fig. 9 had been completed, and therefore the curve given in the figure correctly represents the boundary of the area of audition while these courses were being run, the point *a* being the termination under that condition of the fourth course of the Cactus. To explain the abnormal line *b c*, we have only to suppose that a change in the velocity of the wind afterward took place, by which its opposition to the sound-wave was diminished; this will account for the greater length of the line; the change however did not reach the light-house until after the vessel had passed the point *b*.

Fig. 9.

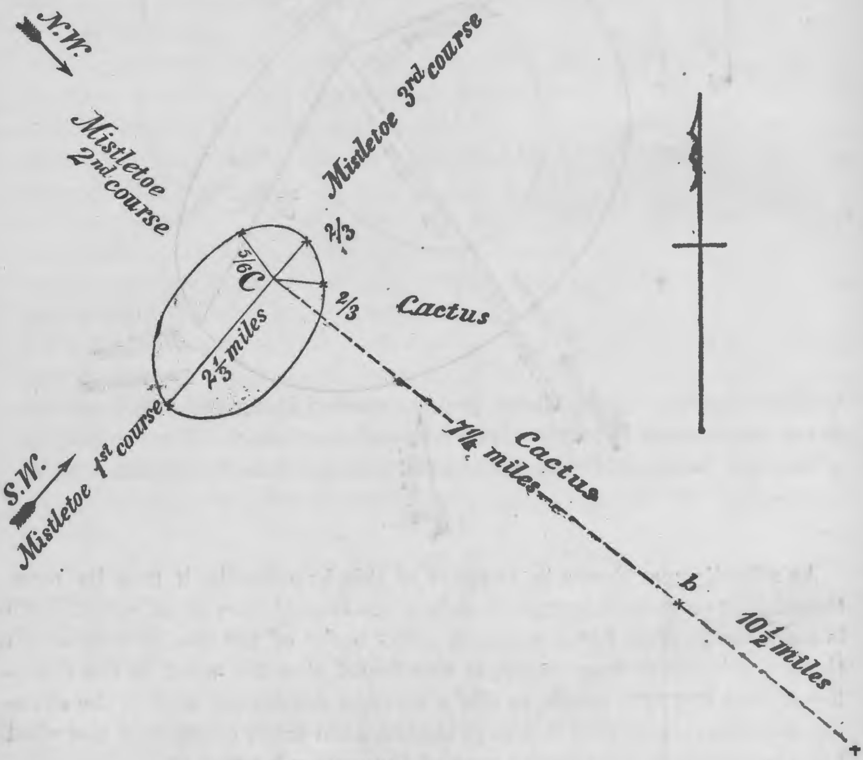


As affording evidence in support of this hypothesis, it may be mentioned that on examining the records of the Signal-Service, of which there is a station at New London, seven miles north of the position at which these observations were made, it was found that the wind in the morning of that day was south, in the afternoon southwest, and in the evening northwest, and that it was probable, as in other cases, that the wind had changed above while the part of the course *b c* was run.

Experiments of September 6.—Barometer, 29.93 inches; thermometer, dry bulb, 74°.5 F. wet bulb, 67°; wind from northwest to southwest, seventeen miles per hour. The wind, though of higher velocity than on any other occasion, was variable. On this day the experiments were principally made with the Mistletoe. The Cactus, being obliged to leave on other duty, ran one course a distance of two-thirds of a mile before the sound of her whistle was lost at the light-house. She afterwards steamed off in the direction C *b* (Fig. 10), noting the sound of the siren, which was lost at the point *b*, afterward regained, and heard distinctly ten and one-half miles distant.

During the passage of the first course of the Mistletoe, the wind at the surface and above was from southwest, the latter being indicated by a cloud passing the zenith. During the second course the wind was variable, changing its direction about 90°, principally from the northwest; while during the third course the wind was again from the southwest. The long course of the Cactus marked on the figure indicates the sound of the siren, from the center outward, as it was heard seven and one-fourth miles, then lost for an interval, and afterward heard again at a distance of three and one-fourth miles farther, making, in all, ten and one-half miles.

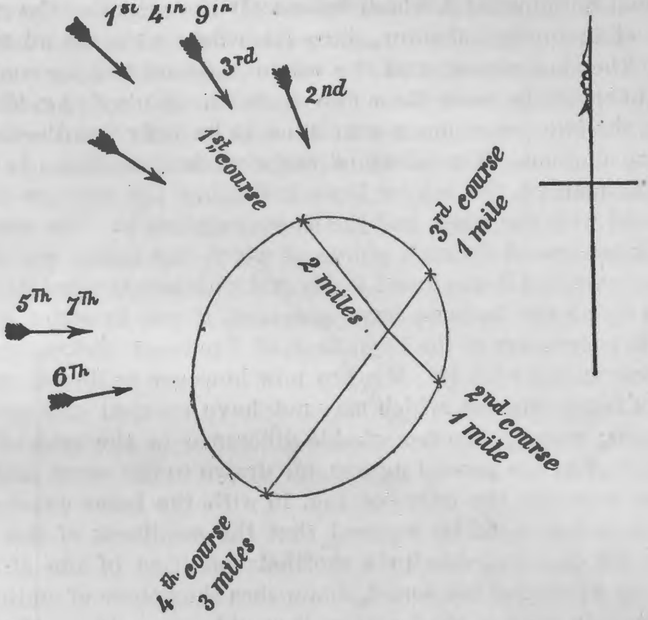
Fig. 10.



Experiments of September 7.—Barometer, 30.1 inches; thermometer, dry-bulb, 73° F. wet-bulb, 62°; wind, eight miles per hour above, and five miles per hour below, tower. The wind was variable, as indicated by the letting-off of balloons, which however did not rise to any great height. The direction of the wind is shown in Fig. 11 by arrows. There is nothing remarkable in the curve of audition of this day. It indicates, as usual, a greater distance toward the side on which the sound was moving with the wind.

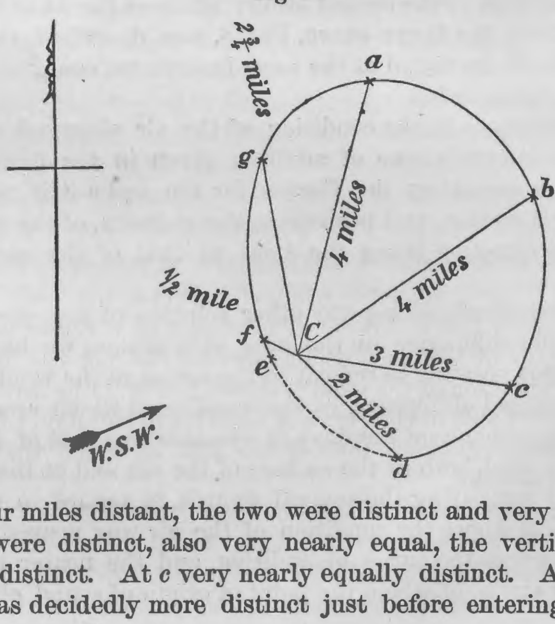
Experiments of September 8.—Barometer, 30.3 inches; thermometer, dry-bulb, 71° F. wet-bulb, 64°.5; wind, west-southwest, fifteen miles per hour at top of tower, nine miles per hour below. Fig. 12 indicates the curve of audition of the vertical siren as compared with that of the

Fig. 11.



horizontal siren. The steamer first proceeded along the line C *a* nearly in the direction of the axis of the horizontal trumpet. For the distance of the first three miles the horizontal trumpet was the louder. At the

Fig. 12.



point *a*, four miles distant, the two were distinct and very nearly equal. At *b* they were distinct, also very nearly equal, the vertical perhaps a little more distinct. At *c* very nearly equally distinct. At *d* the vertical siren was decidedly more distinct just before entering the optical shadow of the light-house tower and the keeper's dwelling. This shadow continued to the point *e*, which was nearly the extent of the acoustic as well as of the optical shadow, since from *d* to *e* the sound was heard from neither instrument, and the origin of sound was too near to cause much difference between these two shadows. From *f* to *a*, through the point *g*, the two instruments continued to be fully heard—the vertical the more distinct. The effect of the wind in this figure is also very distinctly marked, the longer lines indicating the distance the sound was heard with the wind, and the shorter against it. The curve of this figure is not traced through points at which the sound was absolutely lost, but at which it was heard feebly and with nearly equal distinctness.

Thus far all the facts we have observed, if not in strict conformity with our conception of the hypothesis of Professor Stokes, are at least not incompatible with it. We are now however to direct attention to a fact of much interest, which may not have escaped the attention of the reader; namely, the remarkable difference in the area of audition as exhibited in the several figures, all drawn to the same scale. Compare, for example, the curve of Fig. 10 with the inner curve of Fig. 8. It might at first sight be inferred that the smallness of the curve in the former case was due to a mottled condition of the atmosphere, which, by absorbing the sound, diminishes the sphere of audition; but, unfortunately for this explanation, it would appear from the observations made by the Cactus within the hour of obtaining the data for describing the curve, that the air was then in a remarkably favorable condition for the transmission of sound, since it was heard ten and a half miles, the ordinary limit of the maximum penetrating power of the instrument—a siren of the second order; while on the 3d of September, the day on which the large curve, Fig. 8, was described, the greatest distance at which the sound of the same instrument could be heard was eight and a quarter miles.

The only difference in the condition of the air observed during the time of describing the curve of audition given in the figure, and the hearing of the sound by the Cactus for ten and a half miles, was a change in the direction, and perhaps in the intensity, of the wind, in the latter case the direction being the same as that of the course of the Cactus.

Before therefore admitting any other solution of the question as to the cause of the difference in the area of audition, we must inquire whether it is not possible to refer it to the action of the wind itself.

The most marked difference in the conditions which apparently affected the phenomenon on the days in question was that of the greater velocity of the wind, both at the surface of the sea and at the top of the tower, and by comparing the several figures in regard to the wind it will be seen that where the condition of the air was nearest that of a calm the larger was the curve of audition, and the nearer the figures approach to a circle, of which the point of origin of sound or the point of perception is the center. From these facts we are inclined to think that sound is not heard as far during a time of high wind in any direction as it is during a perfect calm, and that it is heard farthest with a gentle wind. This conclusion, which was not anticipated at the beginning of these investigations, is we think in strict conformity with the hypothesis adopted. In the case of sound moving against a strong wind, the sonorous waves being thrown up above the ears of the observer, the sphere of audition in that direction is without question greatly diminished; and that it should be also diminished when sound is moving with a strong wind having a greater velocity above than below is not difficult to conceive. In this case the sound-wave will be so thrown down against the earth, and so much of it absorbed, as to weaken the intensity of that part which reaches the ear, while in the case of a feeble wind, moving faster above than below, the portion of the wave thrown down from above will only be sufficient to compensate for the smaller loss by friction, and thus the sound may be heard at a greater distance than in still air. But on this point, as well as others, further experiments are required.

While we consider the wind as the principal agent in producing the abnormal phenomena of sound, we do not by any means regard it as the sole agent. Prof. Osborn Reynolds, of Owens College, Manchester, without any knowledge of what was doing in America on this subject, instituted a series of experiments on the effect of wind upon sound, and finally adopted precisely the same hypothesis which we have used for generalizing the observed phenomena. He has however in a very ingenious and important paper, presented to the Royal Society in 1874, extended the same principle to the effect of heat in changing the form of the sound-wave, and has shown, both by reasoning and experiment, that the normal direction of the sound-wave in still air, instead of proceeding horizontally should be turned upward, on account of the greater velocity of sound near the earth, due to the greater heat of the strata in that position than of those above. This principle, which indicates the existence of a true refraction of sound independent of the motion of the medium, is undoubtedly applicable as a modifying influence to the phenomena we have recorded. It produces however only a slight effect in the case we have last mentioned, since the observation on board the Cactus shows the condition of the air was that of little acoustic absorption. It would nevertheless favor the hypothesis that sound in perfectly still air of homogeneous density could be heard farther than sound in a moving medium, or in one of unequal temperature. This is also in accordance with the fact repeatedly observed in arctic regions, in which the sound of the human voice is heard at great distances during times of extreme cold. In this case, the air is of a uniform temperature above and below, but of diminished elasticity, and should, on this account, transmit sound with less intensity; and yet the audibility is increased, which is explained by the assumption that its stillness and uniformity of temperature more than compensate for the diminished elasticity. The same may be said with regard to the audibility of sound during a fog, which usually exists during extreme stillness of the air.

Whatever be the cause of the variation in the limit of audition as exhibited in the diagrams, it is less efficient than the ordinary action of the wind in producing the same phenomena. This is evident from the fact that while the ratio of the extreme variation in the limits of audition in the first case is not more than 1:3, in the second it is that of 1:5.

Moreover, when the effect of the wind on the audition of sound in relation to elevation is considered, we think we are fully warranted in asserting, as we did in our last report, that the wind is a more efficient cause of the variability of the penetration of sound than the invisible acoustic clouds adopted by Professor Tyndall for the explanation of the phenomena.

The object of these investigations, as stated at the beginning of this report, was to obtain facts which might serve to establish the true theory of the abnormal phenomena of sound, an object, independent of its scientific interest, of much practical importance in its application to fog-signals. Although the observations were not as perfect as we could wish in many respects, from want of certain appliances, they are yet sufficient we think to establish principles of much practical value. For example, if the mariner in approaching a fog-signal while the wind is blowing against the sound fails to perceive it on deck, he will probably hear it by ascending to the mast-head; or, in case a sound from a given station is constantly obscured in a certain direction, while it is audible in adjacent directions, we may attribute it to a sound-shadow produced by some interposing object. If again, the obscuration of sound in a given direction is only observed during a wind moving against the sound, the cause will probably be found in a lateral refraction, due to the retardation of the current of wind against a perpendicular wall or cliff, as in the case observed at Block Island, August 19. The subject however is one of great complexity, and requires further investigation, but the results thus far obtained may be considered as furnishing the preliminary data on which to found more precise observations. These should be made with the aid of a number of steamers simultaneously employed, each furnished with anemometers and balloons for determining with more accuracy the direction and velocity of the wind.

We hope to renew the investigations during next summer, and in view of this have directed that in the mean time the light-keepers at Block Island and at Point Judith shall continue to sound their sirens a certain length of time every Monday, noting the direction and velocity of the wind, the temperature and pressure of the air, and the audibility of the sound as it comes reciprocally from each instrument.

It is shown, from the results thus far obtained from these reciprocal observations, that sound is occasionally heard more distinctly against the wind than in a contrary direction. We think however that these instances are generally followed by a change in the direction of the wind at the surface of the earth.

LIGHT-HOUSE BOARD, *October*, 1875.

PART V.—INVESTIGATIONS IN 1877.*

On account of the occurrence of the Centennial Exhibition, which absorbed most of the time of the officers of the Light-House Board not devoted to ordinary light-house service, but few observations were made relative to sound in 1876, and an account of what were made is incorporated in the following report.

Agreeably to previous engagement, I visited Portland, Me., to make some investigation in regard to an abnormal phenomenon of sound, which was noticed in a former report. We left Portland on the afternoon of September 3, 1877, in the steamer Iris, which had been fitted up during the year under the direction of the inspector, Commander H. F. Picking, and was in excellent condition, and well adapted to the duty of a light-house tender. The party consisted of General J. C. Duane, engineer of the first district; Commander H. F. Picking, inspector of the first district; Mr. Edward L. Woodruff, assistant engineer of the third district; Mr. Charles Edwards, assistant engineer of the first district, and myself.

We first examined one of the automatic whistling-buoys invented by Mr. Courtenay, of New York. This was in place and emitting sounds at a station called Old Anthony, off Cape Elizabeth, about nine miles from Portland. On approaching it at right angles to the direction of the wind, we heard it at the distance of a mile. But the sound did not appear loud even within a few rods. It was however of considerable quantity, being from a locomotive whistle of ten inches in diameter. The instrument is operated by the oscillation of the waves, which at this time were not of sufficient height to move it vertically through a space of more than one foot. It emitted a sound at each oscillation. This invention consists of a large pear-shaped buoy about twelve feet in diameter at the water-surface, and floats about twelve feet above the same plane. In the interior of this buoy is a large tube or hollow cylinder, three feet in diameter, extending from the top through the bottom to a depth of about thirty feet below the latter. This tube is open at the bottom, but projects air-tight through the upper part of the buoy, and is closed with a plate having three orifices in it, two for letting in the air into the tube, and one between the others for letting it out to operate the whistle. These orifices are connected with three tubes which extend downward to near the level of the water, where they pass through a diaphragm which divides the cylinder into two parts.

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*From the Report of the Light-House Board for 1877.

When the buoy rises, the water in the cylinder by its inertia retains its position, and a partial vacuum is formed between the head of the column and the diaphragm, into which the air is drawn through two of the tubes, and when the buoy descends, the escape through the injection-tube being prevented by valves, it is forced out of the inner tube and actuates the whistle.

The mooring-chain, which is sixty fathoms in length, is attached to the cylinder at a point just below the buoy, and is secured to a large stone weighing about six tons. The apparatus rides perpendicularly.

The sound in this instrument is not produced merely by the difference in hydrostatic pressure of the water in the two positions of the buoy, but by the accumulated effect of impulse generated by the motion of the apparatus.

Plans have been devised, but have not yet been perfected, to condense the air in the buoy by the effect of repeated oscillations, until a valve loaded to a definite pressure would open automatically and allow the air to escape. In this way the sound from the accumulated pressure would be produced at intervals to a greater or less extent, and would serve to diversify the character of the sound so as to enable the mariner to distinguish different locations. The invention, as it is, is considered a valuable addition to the aids to navigation, has received the unqualified approbation of all navigators on this coast who are acquainted with its operation, and will probably be introduced in all countries where its merits are known. Experience has shown that it can be permanently moored in deep water, and that vessels can safely approach it within the nearest distance, and take perfect departure from it.

The Light-House Board has adopted this buoy as one of its permanent aids to navigation, and will in time introduce it at all points where its presence will be of importance to the navigator. In order to obtain reliable data as to the operations of the automatic buoy, Commander Picking has established a series of observations at all the stations in the neighborhood of the buoys, giving the time of hearing it, the direction of the wind, and the state of the sea, from which it appears that in the month of January, 1877, one of these buoys was heard every day at a station one and one-eighth miles distant; every day but two at one two and one-quarter miles distant; fourteen times at one seven and one-half miles distant, and four times at one eight and one-half miles distant. It is heard by the pilots of the New York and Boston steamers at distances of from one-fifth to five miles, and has been frequently heard by the inspector of the first light-house district at a distance of nine miles, and even, under the most favorable circumstances, fifteen miles.

We sailed around the buoy and observed the difference in the intensity of sound in regard to the direction of the wind, which was at the time a fresh breeze of from twelve to fifteen miles per hour, from the westward, the greatest intensity being apparently at points forty-five degrees on either side of the axis of the wind. The effect however was not very definitely marked, though the sound on the whole appeared to be greater on the semi-circumference of the circle to the leeward; but the velocity of the wind was so great that the noise produced by it on the rigging of the vessel prevented the effects from being definitely observed.

Experiments have been made with this buoy carrying whistles of different sizes, the result being that a whistle of less than ten inches diameter does not give a sound which can be heard as far as one of the latter size, although it appears to the ear near by equally loud.

There is a difference between the quantity of sound and the loudness. Two sounds may be equally loud when heard near by, yet differ very much in regard to their being heard at a distance, the loudness depending upon the intensity of sound or on the amplitude of vibration of the sounding body, while the quantity of sound depends on the extent of the vibrating surface.

The size of the whistle must be limited by the quantity of air ejected at each oscillation of the buoy. The fact that the ten-inch whistle gives a sound which can be heard farther than one of eight inches appears to have a bearing on the question (the actuating force being the same) of the united effect of two sounds of the same quantity and pitch, since the sound from several parts of the circumference of the larger whistle may be considered as a union of several sounds of less quantity.

After these observations on the automatic buoy we proceeded along the coast to White Head, at the entrance of Penobscot Bay, a distance of sixty miles, which we reached at about twelve o'clock at night, and cast anchor in Seal Harbor, near the White Head light-house.

Our first operation next morning was the examination of an automatic fog-bell, invented by Mr. Close, and which has been erected by a special appropriation of Congress. It is very simple in conception, and would do good service in southern latitudes, where it would not be affected by the ice. It consists of an upright shaft thirty-two feet long, fastened to the rock beneath the water, and kept in a vertical position by a series of iron rods serving as braces. Around this shaft is a hollow metallic float, having sufficient buoyancy by the motion of the waves to elevate a vertical rod having at the upper end a rack gearing into a ratchet-wheel. By means of projecting pins on the surface of the wheel the hammer of the bell is elevated and the bell sounded at each descent of the float. This arrangement is the most simple and efficient of any of the kind of which we have any knowledge.

The objection to it is its liability to be deranged by the action of ice and the rusting of the parts from exposure to the weather.

Our next operation at this place was the examination of the remarkable abnormal phenomenon, which was the principal object of our excursion. It has been frequently observed by the captains of the steamers plying between Boston and New Brunswick, and has also been noticed on two different occasions by officers of the light-house establishment. The phenomenon, as reported by these authorities, consists in hearing the sound distinctly on approaching the station at the distance of from six to four miles, then losing it through a space of about three miles, and not hearing it again until within about a quarter of a mile of the instrument, when it becomes suddenly audible in almost full power. This phenomenon is always noticed when the vessel is approaching the signal from the southwest, and the wind is in the same or in a southerly direction, and therefore opposed to the direction of the sound from the station, which is the case during a fog. Commander Picking, having frequently received complaints from masters of vessels as to losing the sound at this place, concluded to verify the facts by his own observation. For this purpose he embraced the opportunity of an inspection-tour in July, 1877, to approach the station from the southwest during a fog. In his own words, he heard the sound distinctly through a space of from six to four miles, then lost it and could hear nothing until within a quarter of a mile of the station, when the blast of the whistle burst forth in full sound. The wind at this time was from the southward, or against the sound. This cessation in the hearing of the sound could not have been due to the failure of the instrument to emit sound, since its operation is automatic when once started, and in this case the fog so lifted on nearing the station as to admit the observation of the puffs of steam emitted at each blast of the whistle.

On a previous occasion General Duane and Mr. Edwards on approaching the same signal from the southwest heard the sound at about six miles distance, then lost it, and did not again hear it until within about a quarter of a mile. The wind in this instance was also the same as that in the observation of Commander Picking, namely, from the southwest.

So well established was this phenomenon that General Duane attempted to remedy the evil by elevating the duplicate whistle (with which every station is provided) to a height twenty-two feet above the level of the other whistle, by placing it on the upper end of a tube. But this arrangement produced no beneficial effect.

In the morning of September 4, 1877, on which we commenced our experiments, the weather was clear, the wind west-southwest, the velocity from ten to twelve miles, remaining nearly constant during the day. Our first object was to verify by direct observation the several features of the phenomenon, and for this purpose we steamed to the southward, or directly to the windward, from the station through the region in which the abnormal phenomena had been noticed. The pressure of the atmosphere, as indicated by an aneroid barometer, was 28.9 inches. The temperature of the air was 67° Fahrenheit; that of the water at various points along our course was 58°, except at two points where the thermometer indicated 57°. This difference was too small to have any perceptible effect on the density of the rapidly moving air which was passing over the surface of the water. As we increased our distance from the signal the sound slightly diminished in loudness until the distance was between a quarter and half a mile, when it suddenly ceased to be heard, and continued inaudible through a distance of about a mile, when it was faintly heard and continued to increase in loudness until we reached the distance of four miles; at this point it was heard with such clearness that the position of the station could be located with facility; but on proceeding farther in the same direction it appeared to diminish gradually except at one point, when a blast, as indicated by the steam issuing from the whistle, was inaudible; but on turning the vessel around the next blast was distinctly heard.

As a second experiment we retraced the same line back to the station and observed the same phenomena in a reverse order. The sound was heard the loudest at a point four miles from the station; afterward it diminished and then became inaudible through a space of two miles, and then suddenly burst forth nearly in full intensity at the distance of a quarter of a mile, and continued loud until the station was reached.

As a third experiment the same line was traversed again, the only difference in the condition of the experiment being that the whistle on the steamer was sounded every minute between the blasts of the signal at the station; and while the observers on the vessel noted the sounds from the latter, those at the station observed the sound from the former. The same phenomena as described in the previous experiments were witnessed by those on board the vessel, but on receiving the report of the observers at the station, it was found that no cessation of the sound from the steamer was observed through the whole distance traversed by the vessel. It should be noted that the whistle at the station is ten inches in diameter, actuated by a pressure of sixty pounds of steam, and that on board the vessel six inches in diameter with twenty-five pounds of steam. It appears from this remarkable result that a feeble sound passes freely through what has been called the region of silence when sent in the direction of the motion of the wind, when a louder sound does not pass in the opposite direction.

As a fourth experiment the vessel proceeded northward on the opposite side of the station to that before traversed, but in the prolongation of its previous course. The sound in this case from the signal to the observers on the vessel was with the wind, while that from the vessel to the observers at the station was against the wind. In this experiment no cessation was observed on the vessel in the hearing of the sound from the station; it was heard with varying intensity to the distance of four and a half miles, and could probably have been heard much farther had our progress not been interrupted by land. On returning to the station the observers there reported that after the vessel had left the station and was scarcely more than a hundred yards distant not a single blast of its whistle was heard. In this case the phenomena which had been observed on the southerly side of the station were exhibited in a reverse order on the northerly side.

In what may be considered the fifth experiment, the vessel being at a distance of four miles from the station on the line traversed in the first two experiments, the sound was heard slightly. The vessel then altered its course so as to steam, as it were, around the signal, keeping at the same distance until the direction of the station from the vessel was nearly at right angles to the direction of the wind; at this point no sound was heard from the station, although it had been slightly heard at points along the curved line traversed in reaching the point mentioned. The vessel then proceeded toward the station in a straight line, but no sound was heard until it approached the latter within one-fourth of a mile. The observers at the station however heard the sound from the vessel through the whole distance.

This experiment was made to ascertain the truth of the general impression that at this place the sound was always heard better coming at right angles or across the wind than in the direction in which it was blowing. The experiment however was found in conformity with the general rule previously established, that the sound was usually heard farthest with the wind, less against the wind, and at an intermediate distance across the wind.

The primary object of these investigations is to determine the mechanical causes to which the phenomena may be referred and from which new conclusions may be deduced, to be further tested by experiment, and such definite views obtained as may be of value in the employment of fog-signals for the uses of the mariner.

For this purpose a number of different hypotheses may be provisionally adopted and each compared with the actual facts observed.

The first hypothesis which has been suggested for the explanation of the phenomena in question is that they are due to some configuration of the land; but on inspecting the Coast-Survey chart of this region it will be seen that the nearest land consists of a series of broken surfaces not rising above the ocean enough to reflect sound or in any way to produce sound-shadows in the region through which the phenomena are observed. This hypothesis therefore is inadmissible.

Another hypothesis is that of what have been called invisible acoustic clouds or portions of atmosphere existing over the water at the region of silence, which might absorb or variously refract the sound. That such a condition of a portion of the atmosphere really exists in some cases is a fact which may be inferred from well-established principles of acoustics, as well as from experimental data. They would occur especially in the case of dissolving clouds, which would be accompanied by local diminutions of temperature, and also from portions of air which have been abnormally heated by contact with warm earth. But, if the phenomena in question were produced by a cloud of this kind, its presence ought to be indicated by transmitting through it the usual set of meteorological instruments. This was done in the foregoing experiments, but no change was observed in the indications either of the thermometer or barometer. Unfortunately we had not a hygrometer in our possession, but this observation was less necessary, since from abundant testimony it is established that the same phenomena are exhibited during a dense fog, in which all parts of the atmosphere for miles in extent must be in a homogeneous condition. Furthermore, a local cloud could not continue to exist in a given space for more than an instant while a wind was blowing with a velocity of from ten to twelve miles an hour. Again, this hypothesis fails entirely to explain the fact that this phenomenon is always observed at nearly the same place, especially during a fog, when the wind is in a southerly direction. Finally, it is impossible to conceive of a cloud so arranged as a screen producing a sound-shadow of greater intensity on one side than on the other.

Another hypothesis is that of the refraction of sound due to the action of the wind. It is an inference from well-established theory, as well as from direct observation, that the sound is refracted by the wind, that it tends to be thrown upward when moving against the wind, and downward with the wind. This result is attributed very properly to the different velocities of the strata, that next the surface being retarded, those above being less retarded.

The upper part of the front of the wave is thus thrown backward, and the direction of the wave turned upward. In the case of the experiment south of the station, the wind passing over a long line of rough sea was moving less rapidly in its lower stratum than in the higher, and consequently the sound-wave was thrown backward above, and, as it issued from the instrument, tended to rise above the head of the observer, and at a certain distance from the origin of the sound, depending upon the difference of velocity above and below, was lost entirely to the observer, and a sound-shadow was thus produced by refraction which is closed in again by the lateral spread of the sound at a given distance.

In the experiment on the other side of the signal, the vessel proceeding to the north, the wind coming to the observer on the vessel had to pass over a rougher surface than that of water, and consequently the difference of velocities above and below, and therefore the refraction would be greater, and consequently the sound from the vessel was almost entirely lost to the observer at the station, while the sound from the station was heard uninterruptedly on the vessel, since it was moving with the wind.

On examining the records of experiments of previous years, I find a number of cases recorded where sounds were heard at a greater distance, while inaudible at a less distance, especially one in connection with the fog-signal at Gull Island, in 1874. In this case the sound, in passing from the signal, was heard distinctly at the distance of about two miles against the wind, then lost for a space of about four and a half, and heard again distinctly for a distance of perhaps one mile. At the same station, during the experiments of 1875, the sound of the whistles of the steamers was heard for a certain distance, then ceased to be heard for a considerable interval, and was then heard again. Furthermore, the pilots of the steamboats from New York to Boston report that the automatic buoy is found to intermit its sound, being heard at a distance, then becoming inaudible, and heard again as the steamer approaches the source of sound.

From all the facts which we have gathered on this subject, I think it highly probable that in all cases in which sound moving against the wind is thrown up above the head of the observer it tends to descend by the lateral spread of the sound-wave and to reach the earth at a distance; the conditions however for the actual production of this effect are somewhat special, and will depend upon the amount of the initial refraction and the quantity of the sound-waves. Besides the lateral spread of the sound-wave there are two other causes sufficient, in certain cases, to bring a portion of the sound-waves which have been elevated in the air back again to the earth: the first is when an upper current of wind is moving in an opposite or approximately opposite direction to that at the surface of the earth, in which case an opposite or downward refraction would take place; and the second is the case in which the surface-wind is terminated above by strata of still air; in this case, also, a reverse refraction, but of less amount, would take place, which would tend to bring the sound-wave downward.

We can readily imagine that an isolated island, cooled by the radiation of the heat by night, would send every morning, in all directions, a current of cold air from its center. In this case, the sound from a whistle placed in the center of the island would be inaudible in a space entirely surrounding it, and thus give rise to a condition mentioned by General Duane, in which a fog-signal appeared to be surrounded by a belt of silence.

The next experiment was made on the morning of the 5th, on leaving the station. In this case we proceeded along the direction of the same line in which the first, second, and third experiments were made the day before. The wind had changed about four points to the southward. As in the preceding experiments, the sound was lost again at the distance of about one-fourth of a mile, but was not distinctly regained, though some of the observers thought they heard it at a distance of two and one-half miles.

The only perceptible difference in the wind on the 5th was that it was a little less rapid, and four points more to the southward.

From a subsequent report of the keepers, the whistle of the vessel was heard continuously as far as the puffs of steam could be observed, a distance six or seven miles. In this case the sound was moving with the wind. These results therefore are in accordance with those previously obtained.

The next experiments were made at Monhegan, an island sixteen miles southwest of White Head. On this island there is a Daboll trumpet actuated by a hot-air engine.

We departed from this station in a westerly direction at an angle of

45° to the right of the direction of the wind, and after proceeding about one mile, as estimated by time, we lost the sound of the signal. We then turned at right angles to our former course and proceeded toward the leeward, keeping about the same distance from the signal, when the sound was regained at a point which probably depended upon the direction of the wind and the axis of the trumpet combined. From this point it was heard to a point to the leeward, and thence we retraced our course at about the same distance and proceeded across the axis of the trumpet toward the windward, where the sound was again lost. The only definite result from this experiment was another case of the sound being heard farther to the leeward than to the windward.

After this experiment we returned to Portland.

An interesting fact may be mentioned in connection with this station, having a bearing upon the protection of light-houses from lightning. The fog-signal is placed on a small island separated from the large island by a water-space of about one-eighth of a mile. General Duane, desiring to connect the light-house and fog-signal by an electrical communication, suspended a wire between the two points and attempted to form a ground connection by depositing a plate of metal in the ground on each island, but to his surprise, though the arrangements were made by a skilled telegrapher, no signal would pass. The two islands being composed of rock and the soil limited in thickness, the conduction was imperfect, and it was only by plunging the plate of metal into the water on each side of the space between the two islands that a signal could be transmitted.

No further experiments on sound were made during this excursion, because the vessel could no longer be spared from more pressing light-house duty in the way of inspection and the stated supply of materials to the stations.

On my return to New York, accompanied by Mr. Woodruff, I took the route by the Western Railway to the Hudson River at Troy. This line was chosen in order to make some investigations relative to any peculiarities of sound which might be observed in the Hoosac tunnel, through which the railroad passes. For this purpose we spent a day at East Windsor, a village situated near the west end of the tunnel, and were very cordially received by the engineers in charge.

The tunnel is four and three-quarters miles in length, twenty-four feet wide, and twenty feet high to the crown of the arch. It ascends slightly from either end to a point near the center, where there is a ventilating-shaft 1,028 feet high extending to the outer air above. In winter, when the external temperature is less than that within the tunnel, there is a constant current from each end toward the center, and in the summer, when the temperatures are reversed, there is a current out of the tunnel at either end, except when the external wind is sufficiently strong, especially from the west, to reverse the direction of the current from one half and direct the stream entirely out of the other entrance. At the time of our visit, there was a gentle current flowing out of both ends.

The only peculiarity of sound which had been observed, as stated by the engineers, was that it was greatly stifled at the time by the smoke with which the air was filled immediately after the passage of a locomotive. So great was this in some cases that accidents were imminent to the workmen, who are constantly occupied in the tunnel in lining the crown of the arch with brick, by the sudden appearance of a locomotive, the approach of which had not been heard.

That the audibility of sound should be diminished by smoke was so contrary to previous conceptions on the subject, since sound is not practically interrupted by fog, snow, rain, or hail, that I was induced to attribute the effects which had been observed to another cause, and to regard the phenomenon as due to an exaggerated flocculent condition of the air in the tunnel; adopting in this instance the hypothesis advanced by Dr. Tyndall, and so well illustrated by his ingenious experiments. The effect which would be produced in the condition of the air in the tunnel by the passage of a locomotive is indicated by the appearance of the emitted steam extending behind the smoke-stack of a locomotive in rapid progress before the observer at a distance. This consists of a long stream composed of a series of globular masses produced by the successive puffs of steam which are emitted at equal intervals. Allowing the diameter of the driving-wheels to be five feet, then since four puffs are made at each revolution of the wheels, a puff of hot steam would be given out at every four feet travelled by the engine, and these puffs mingling with the air at the ordinary temperature would produce an exaggerated flocculent condition. On our expressing a desire to witness the effect upon sound of the passage of a locomotive through the tunnel, Mr. A. W. Locke, one of the engineers who had charge of the western section, politely offered us the means of experimenting on this point, and also of passing leisurely through the tunnel on a hand-car.

To observe the effect of a locomotive on the sound we took advantage of the entrance of a freight train, impelled by two engines, the extra one being necessary to drive the load up the inclined plane to the middle of the tunnel, where it was detached and returned along the same line, while the train was drawn the remaining distance along the eastern decline by a single engine. In order to make the experiment with regard to sound the time was accurately noted during which the noise of the entering engines could be distinctly heard, which would give approximately the distance the sound travelled through the flocculent atmosphere produced by the locomotive before becoming inaudible, and again the time was noted from the first hearing of the returning engine until it reached the end of the tunnel. In the mean time the current of air blowing through the tunnel had removed a considerable portion, at least, of the flocculent atmosphere, so that the seund in this case came through an atmosphere of comparative uniformity of temperature, or one much less flocculent than the other; the result was that the duration of sound in the first case was about a minute, while in the second it was upward of two minutes. The darkness in the tunnel, on account of the smoke, was so profound immediately after the passage of a locomotive, that with two large torches, charged with mineral oil, the sides of the tunnel at a distance of six feet could scarcely be observed; while in the other half of the tunnel, where no smoke existed, the eastern opening could be observed like a star in the distance of upward of two miles. It was therefore not surprising that the stifling of the sound which was observed should be referred to the smoke as a palpable cause, and that the more efficient one of the varying density or flocculent condition should be disregarded.

The method of determining by experiment the question as to which of these causes was the efficient one did not occur to me until we had left the tunnel, and then the simple expedient suggested itself to me, for the purpose of repeating the experiment, that instead of locomotives charged with wood, two locomotives charged with charcoal or coke—which emit no smoke, but only transparent gases principally carbonic acid—should be used in an experiment similar to the one just described. This experiment Mr. Locke has kindly promised to perform as soon as a convenient opportunity shall occur.

The opportunity was embraced while at the mouth of the tunnel to make some observations which might have a bearing upon the phenomena of the aërial echo. For this purpose, advantage was taken of a large tool-chest, which happened to be placed about twenty or thirty feet within the western mouth of the tunnel. By slamming down violently the cover of this chest, a loud sound of an explosive character was produced, from which a prolonged echo was returned from the interior of the tunnel. This echo was slightly intermittent, suddenly increasing in loudness at intervals for a moment, and again resuming its uniform intensity. This effect was attributed to projecting pieces of rock in that part of the tunnel which had not been lined with brick. An echo was however evidently returned from that portion of which the sides were not projecting, which I would consider an effect of the same cause which produces the aërial echo.

AËRIAL ECHOES.

During the year 1877, (as also in 1876,) series of experiments were made on the aërial echo, in which I was assisted—in the first series by General Woodruff, engineer of the third light-house district,—and in the second series by Edward Woodruff, assistant engineer of the same district. These experiments were made principally at Block Island, but also at Little Gull Island. Especial attention has been given to this phenomenon, which consists in a distinct echo from the verge of the horizon in the direction of the prolongation of the axis of the trumpet of the siren, because the study of it has been considered to offer the easiest access to the solution of the question as to the cause of all the abnormal phenomena of sound, and also because it is in itself an object of much scientific interest.

In my previous notice of this phenomenon, in the report of the light-house board for 1874, I suggested that it might be due to the reflection from the crests of the waves of the ocean; but as the phenomenon has been observed during all conditions of the surface of the water, this explanation is not tenable.

Another hypothesis has been suggested, that it is due to a flocculent condition of the atmosphere, or to an acoustic invisible cloud, of a density in different parts differing from that of the general atmosphere at the time. To test this hypothesis experimentally, the large trumpet of the siren was gradually elevated from its usual horizontal position to a vertical one. In conception, this experiment appears very simple, but on account of the great weight of the trumpet, it required the labor of several men for two days to complete the arrangements necessary to the desired end. The trumpet, in its vertical position, was sounded at intervals for two days, but in no instance was an echo heard from the zenith, but one was in every case produced from the entire horizon. The echo appeared to be somewhat louder from the land portion of the circle of the horizon than from that of the water. On restoring the trumpet to its horizontal position, the echo gradually increased on the side of the water, until the horizontal position was reached, when the echo, as usual, appeared to proceed from an angle of about twenty degrees of the horizon, the middle of which was in the prolongation of the axis of the trumpet. A similar experiment was made with one of the trumpets of the two sirens at Little Gull Island. In this case the trumpet was sounded in a vertical position every day for a week with the same result. On one occasion it happened that a small cloud passed directly over the island on which the light-house is erected, and threw down on it a few drops of rain. At the moment of the passage of this cloud the trumpet was sounded, but no echo was produced.

From these experiments it is evident that the phenomenon is in some way connected with the plane of the horizon, and that during the continuance of the experiment of sounding the trumpets while directed toward the zenith no acoustic cloud capable of producing reflection of sound existed in the atmosphere above them.

Another method of investigating this phenomenon occurred to me, which consisted in observing the effects produced on the ears of the observer by approaching the origin of the echo. For this purpose, during the sounding of the usual interval of twenty seconds of the large trumpet at Block Island, observations were made from a steamer which proceeded from the station into the region of the echo and in the line of the prolongation of the axis of the trumpet, with the following results:

1. As the steamer advanced, and the distance from the trumpet was

increased, the loudness of the echo diminished, contrary to the effect of an echo from a plane surface, since in the latter case the echo would have increased in loudness as the reflecting surface was approached, because the whole distance travelled by the sound-wave to and from the reflector would have been lessened. The effect however is in accordance with the supposition that the echo is a multiple sound, the several parts of which proceed from different points at different distances of the space in front of the trumpet, and that as the steamer advances toward the verge of the horizon, it leaves behind it a number of the points from which the louder ones proceed, and thus the effect upon the ear is diminished as the distance from the trumpet is increased.

2. The duration of the echo was manifestly increased, in one instance, from five seconds, as heard at the mouth of the trumpet, to twenty seconds.

This would also indicate that the echo is a multiple reaction of varying intensities from different points, and that at the place of the steamer the fainter ones from a greater distance would be heard, which would be inaudible near the trumpet.

3. The arc of the horizon from which the echo appeared to come was also increased in some cases to more than three times that subtended by the echo at the place of the trumpet. This fact again indicates that the echo consists of multiple sounds from various points at or near the surface of the sea, the angle which the aggregate of these points subtend necessarily becoming greater as the steamer advances.

But perhaps the most important facts in regard to the echo are those derived from the series of observations on the subject, made by Mr. Henry W. Clark, the intelligent keeper of the principal light-house station on Block Island, and by Joseph Whaley, keeper of the Point Judith light-house. Mr. Clark was furnished with a time-marker to observe the duration of the echo, and both were directed to sound the trumpets every Monday morning for half an hour, noting the temperature, the height of the barometer, the state of the weather as to clearness or fog, the direction and intensity of the wind, and the surface of the ocean.

From the observations made at these two points, for more than two years at one station and over a year at the other, the echo may be considered as produced constantly under all conditions of weather, even during dense fogs, since at Block Island it was heard 106 times out of 113, and at Point Judith 50 times out of 57, and on the occasions when it was not heard the wind was blowing a gale, making a noise sufficiently intense to drown the sound of the echo. These results appear to be sufficient to disprove the hypothesis that the phenomenon is produced by an acoustic cloud accidentally situated in the prolongation of the axis of the trumpet. It must be due to something more permanent in its effects than that from a portion of air differing from that of the general atmosphere in temperature or density, since such a condition cannot exist in a dense fog embracing all the region of the locality of the phenomenon. Indeed, it is difficult to conceive how the results can be produced, even in a single instance, from a flocculent portion of atmosphere in the prolongation of the axis of the trumpet, since a series of patches of clouds of different temperature and densities would tend to absorb or stifle by repeated reflections a sound coming from their interior rather than to transmit it to the ear of the observer.

The question, therefore, remains to be answered: what is the cause of the aërial echo? As I have stated, it must in some way be connected with the plane of the horizon. The only explanation which suggests itself to me at present is that the spread of the sound which fills the whole atmosphere from the zenith to the horizon with sound-waves may continue their curvilinear direction until they strike the surface of the water at such an angle and direction as to be reflected back to the ear of the observer. In this case the echo would be heard from a perfectly flat surface of water, and as different sound-rays would reach the water at different distances and from different azimuths, they would produce the prolonged character of the echo and its angular extent along the horizon.

While we do not advance this hypothesis as a final solution of the question, we shall provisionally adopt it as a means of suggesting further experiments in regard to this perplexing question at another season.

General Conclusions.

From all the experiments which have been made by the Light-House Board in regard to the transmission of sound in free air and those derived from other observations which can be fully relied upon, the following conclusions may be considered established, subject however to such further modification and extension as subsequent investigation may seem to indicate:

1. The audibility of sound at a distance (the state of the atmosphere being constant) depends upon the character of the sound. The distance through which a sound may be heard is governed by the pitch, the loudness, and the quantity of sound. The pitch or frequency of the impulses in a given time must not be too high, otherwise the amplitude of vibration will be too small to allow a sufficient quantity of air to be put into motion; neither must the pitch be too low, for in this case the motion of the atoms of air in the sound-wave will not be sufficiently rapid to convey the impulse to a great distance. Again, the greater the loudness of the sound, which depends upon the amplitude of the vibrations of the sounding-body, the greater will be the distance at which it will be heard. And finally, the greater the quantity of sound, which depends upon the magnitude of the vibrating surface, the greater will be the distance to which it is audibly transmitted. These results are derived from observations on the siren, the reed-trumpet, and the automatic buoy. The effect of quantity of sound is shown in the fact that in sounding different in-

struments at the same time, it was found that two sounds apparently of the same loudness were heard at very different distances.

2. The audibility of sound depends upon the state of the atmosphere. A condition most favorable to the transmission of sound is that of perfect stillness and uniform density and temperature throughout. This is shown by the observations of Parry and other Arctic explorers; although in this case an efficient and co-operating cause is doubtless the downward refraction of sound due to the greater coldness of the lower strata of air, as first pointed out by Professor Reynolds. Air however is seldom in a state of uniform density, but is pervaded by local currents, due to contact with portions of the earth unequally heated, and from the refractions and reflections to which the sound-wave is subjected in its passage through such a medium it is broken up and lost to the ear at a less distance.

3. But the most efficient cause of the loss of audibility is the direct effect produced by the wind. As a general rule, a sound is heard farther when moving with the wind than when moving against it. This effect, which is in conformity with ordinary observation, is not due to an increase of velocity of the sound-wave in one direction and a diminution in the other by the motion of the wind except in an imperceptible degree; for since sound moves at the rate of about seven hundred and fifty miles an hour, a wind of seven miles and a half an hour could increase or diminish the velocity of the sound-wave only one per cent. while the effect observed is in some cases several hundred per cent. It is however due to a change in its direction. Sound moving with the wind is refracted or thrown down toward the earth; while moving against the wind it is refracted upward and passes over the head of the observer, so as to be heard at a distance at an elevation of several hundred feet when inaudible at the surface of the earth.

4. Although, as a general rule, the sound is heard farther when moving with the wind than when moving against it, yet in some instances the sound is heard farthest against the wind; but this phenomenon is shown to be due to a dominant upper wind, blowing at the time in an opposite direction to that at the surface of the earth. These winds are not imaginary productions invented to explain the phenomena, but actual existences, established by observation, as in the case of the experiments made at Sandy Hook, in 1874, by means of balloons, and from the actual motion of the air in the case of northeast storms, as observed at stations on the coast of Maine.

5. Although sound issuing from the mouth of a trumpet is at first concentrated in a given direction, yet it tends to spread so rapidly that at the distance of three or four miles it fills the whole space of air inclosed within the circuit of the horizon, and is heard behind the trumpet nearly as well as at an equal distance in front of its mouth. This fact precludes the use of concave reflectors as a means of increasing the intensity of sound in a given direction; for although at first they do give an increase

of sound in the direction of the axis, it is only for a comparatively short distance.

6. It has been established, contrary to what has formerly been thought to be the case, that neither fog, snow, hail, nor rain, materially interferes with the transmission of loud sounds. The siren has been heard at a greater distance during the prevalence of a dense and widely-extended fog than during any other condition of the atmosphere. This may however be attributed to the uniform density and stillness of the air at the time.

7. In some cases sound-shadows are produced by projecting portions of land or by buildings situated near the origin of the sound, but these shadows are closed in by the spread of the sound-waves, and thus exhibit the phenomenon of sound being heard at a distance and afterwards lost on a nearer approach to the station.

8. It frequently happens on a vessel leaving a station, that the sound is suddenly lost at a point in its course, and after remaining inaudible some time, is heard again at a greater distance, and is then gradually lost as the distance is farther increased. This phenomenon is only observed when the sound is moving against the wind, and is therefore attributed to the upward refraction of the sound-wave, which passes over the head of the observer and continues an upward course until it nearly reaches the upper surface of the current of wind, when the refraction will be reversed and the sound sent downward to the earth; or the effect may be considered as due to a sound-shadow produced by refraction, which is gradually closed in at a distance by the lateral spread of the sound-wave near the earth, on either side, in a direction which is not affected by the upward refraction. Another explanation may be found in the probable circumstance of the lower sheet of sound-beams being actually refracted into a serpentine or undulating course, as suggested in the Appendix to the Report of the Light-House Board for 1875. (See page 513.) Such a serpentine course would result from successive layers of unequal velocity in an opposing wind; as being retarded at and near the surface of the earth, attaining its maximum velocity at a height of a few hundred feet, and then being again retarded at greater elevations, by the friction of upper counter currents or stationary air. In some cases the phenomenon is due to one or the other of these causes, and in other cases to all combined. That it is not due to the obstructing or screening effects of an abnormal condition of the atmosphere is shown by the fact that a sound transmitted in an opposite direction, through what is called the region of silence, passes without obstruction. It is probable from all the observations, that in all cases of refraction of a sound moving against the wind it tends again to descend to the earth by the natural spread of the sound.

9. The existence of a remarkable phenomenon has been established, which is exhibited in all states of the atmosphere during rain, snow, and dense fog, to which has been given the name of aërial echo. It consists

of a distinct echo, apparently from a space near the horizon of fifteen or twenty degrees in azimuth, directly in the prolongation of the axis of the trumpet. The loudness of this echo depends upon the loudness and quantity of the original sound, and therefore it is produced with the greatest distinctness by the siren. It cannot be due to the accidental position of a flocculent portion of atmosphere, nor to the direct reflection from the crests of the waves, as was at first supposed, since it is always heard except when the wind is blowing a hurricane.

As a provisional explanation, the hypothesis has been adopted that in the natural spread of the waves of sound, some of the rays must take such a curvilinear course as to strike the surface of the water in an opposite direction and thus be reflected back to the station or location of the origin of the sound.

LIGHT-HOUSE BOARD, *October*, 1877.

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