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Annual Report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the institution for the year 1876

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44TH CONGRESS, 2d Session. | SENATE. | MIS. DOC. No. 46.

ANNUAL REPORT

OF THE

BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION,

SHOWING

THE OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION FOR THE YEAR 1876.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1877.

FORTY-FOURTH CONGRESS—SECOND SESSION.

CONGRESS OF THE UNITED STATES,
In the House of Representatives, March 1, 1877.

The following resolution, originating in the House of Representatives February 28, 1877, has this day been concurred in by the Senate:

Resolved by the House of Representatives, (the Senate concurring,) That ten thousand five hundred copies of the Report of the Smithsonian Institution for the year 1876 be printed, one thousand copies of which shall be for the use of the Senate, three thousand copies of which shall be for the use of the House of Representatives, and six thousand five hundred copies for the use of the Smithsonian Institution: *Provided*, That the aggregate number of pages shall not exceed five hundred, and that there be no illustrations, except those furnished by the Smithsonian Institution.

Attest:

GEO. M. ADAMS, *Clerk*.

LETTER

FROM THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

TRANSMITTING

The annual report of the Smithsonian Institution for the year 1876.

SMITHSONIAN INSTITUTION,
Washington, February 16, 1877.

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 1876.

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

JOSEPH HENRY,
Secretary Smithsonian Institution.

Hon. SAM. J. RANDALL,
Speaker of the House of Representatives.

ANNUAL REPORT OF THE SMITHSONIAN INSTITUTION FOR 1876.

This document contains:

1. The annual report of the Secretary, giving an account of the operations and condition of the establishment for the year 1876, 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 1876, and the estimates for 1877.

3. The proceedings of the Board of Regents for the sessions of January and February, 1877.

4. A general appendix, consisting principally of 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.

ULYSSES S. GRANT, 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.)
JOSEPH HENRY, Secretary, (or Director of the Institution.)

REGENTS OF THE INSTITUTION.

MORRISON R. WAITE, Chief-Justice of the United States, *President of the Board.*
T. W. FERRY, acting Vice-President of the United States.
H. HAMLIN, member of the Senate of the United States.
J. W. STEVENSON, member of the Senate of the United States.
A. A. SARGENT, member of the Senate of the United States.
HIESTER CLYMER, member of the House of Representatives.
BENJAMIN H. HILL, member of the House of Representatives.
GEO. W. McCRARY, member of the House of Representatives.
JOHN MACLEAN, citizen of New Jersey.
PETER PARKER, citizen of Washington.
ASA GRAY, citizen of Massachusetts.
J. D. DANA, citizen of Connecticut.
HENRY COPPEE, citizen of Pennsylvania.
GEORGE BANCROFT, citizen of Washington.

EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS.

PETER PARKER. JOHN MACLEAN. GEORGE BANCROFT.

MEMBERS EX OFFICIO OF THE INSTITUTION.

U. S. GRANT, President of the United States.
T. W. FERRY, Vice-President of the United States.
M. R. WAITE, Chief-Justice of the United States.
H. FISH, Secretary of State.
LOT M. MORRILL, Secretary of the Treasury.
J. D. CAMERON, Secretary of War.
G. M. ROBESON, Secretary of the Navy.
J. N. TYNER, Postmaster-General.
Z. CHANDLER, Secretary of the Interior.
A. TAFT, Attorney-General.
ELLIS SPEAR, Commissioner of Patents.

OFFICERS AND ASSISTANTS OF THE SMITHSONIAN INSTITUTION AND NATIONAL MUSEUM.

JOSEPH HENRY,
Secretary, Director of the Institution.
SPENCER F. BAIRD,
Assistant Secretary and Curator of the National Museum.
WILLIAM J. RHEES,
Chief Clerk.
DANIEL LEECH,
Clerk in charge of Correspondence.
CLARENCE B. YOUNG,
Clerk in charge of Accounts.
HERMANN DIEBITSCH,
Clerk in charge of Exchanges.
Miss J. A. TURNER,
Clerk in charge of Library.
Miss M. E. GRIFFIN,
Clerk in charge of Distribution of Publications.
S. G. BROWN,
Clerk in charge of Freight.

Prof. G. B. GOODE,
Assistant Curator of the National Museum.
Prof. F. M. ENDLICH,
In charge of Mineralogical Division.
Prof. ROBERT RIDGWAY,
In charge of Ornithological Division.
Prof. W. H. DALL,
In charge of Conchological Division.
Prof. EDW. FOREMAN,
In charge of Ethnological Division.
T. W. SMILLIE,
Photographer.
JOSEPH PALMER,
Taxidermist.
JOSEPH HERRON,
Janitor.

REPORT OF PROFESSOR HENRY, SECRETARY OF THE SMITHSONIAN INSTITUTION, TO THE BOARD OF REGENTS, FOR THE YEAR 1876.

GENTLEMEN: I have the honor herewith to present to your board the report of the condition and operations of the Smithsonian Institution for the year 1876, it being the thirtieth report which I have been permitted to submit to your honorable body.

INTRODUCTION.

The long term of service of the principal executive officer of the Institution, and the few changes in the presiding officer of the Board of of Regents, have been attended with the important result of an uninterrupted continuity in the policy of the management of the establishment. A definite conception of the will of Smithson, and of the means best adapted to realize its intention, was clearly apprehended at the beginning, and a plan proposed and partially adopted which would carry out, in the most effectual manner, the ideas expressed in the terms of the bequest. Unfortunately Congress did not delegate to the Board of Regents the power of entirely organizing the Institution, but specified certain objects which should be included in the plan adopted. It will, however, be seen by an examination of the whole series of annual reports, that while due regard has been had to the requirements of Congress, the prominent object kept constantly in view has been the full introduction of the plan of increasing and diffusing knowledge by means of researches, publications, and exchanges. This plan, which is known as that of *active operations*, and which has received the approbation of the scientific world, was not generally understood at the time of the organization of the establishment. The value of scientific research was not as highly appreciated then as at the present day, and therefore it is not surprising that Congress should devote the income of the fund principally to the formation of a library, a museum, and a gallery of art.

These objects, though important in themselves, are all of a local character, being principally confined in their influence to the city of Washington, and therefore could not realize the liberal intention of Smithson, which includes in its comprehensive scope the intellectual advancement of mankind.

Although a majority of the Board of Regents were in favor of the plan of active operations, they did not think it prudent to ask Congress at that time to reconsider the plan which it had adopted, but concluded to proceed without delay in executing the measures prescribed, while at the same time they availed themselves of the privilege granted in one of the sections of the act of organization to partially introduce and gradually develop the plan of active operations.

In conformity with the act of Congress, a building has been erected at a cost of upwards of $500,000. A library of 70,000 volumes has been collected—principally of a class of books of the highest value, consisting of the transactions and proceedings of learned societies—with provision for its annual increase. The museum of the Government has been enlarged to more than ten times its original size, a new department having been added to it, viz, that of American Indian Ethnography, which is more extended and varied in specimens than any other ever established. A gallery of art has also been formed, which is especially rich in illustrations of industrial arts. In addition, a considerable proportion of the income of the Smithson fund has been expended on the improvement of the grounds surrounding the building. In short, every item of the original requirement of Congress has received due attention.

To effect these objects, and at the same time to develop the plan of active operations, it became necessary to increase the income of the fund, and this has been accomplished by the adoption of a system of rigid economy and by a judicious investment of the savings of the income.

The original amount of the fund of $541,379 has been increased to $714,000. Instead of forming the library by the purchase of books, it has been created principally through exchanges, while the expense of maintaining it has been obviated by depositing the books in the Library of Congress. The care of the grounds, which was a very expensive item, has been assumed by the Government, and the cost of maintaining the museum is now defrayed by an annual congressional appropriation. The Institution having thus happily been relieved from the support of these burdens, is now, at the end of the third decade of its history, in a condition to fully realize the conception of its character as originally set forth in the first annual report of the Secretary, while the success of the plan of active operations has fully vindicated the propriety of its adoption. Through its operation the Institution has advanced almost every branch of science, and has made the name of Smithson known wherever civilization exists.

It has published twenty-one quarto volumes of transactions, entitled "Smithsonian Contributions to Knowledge," twelve octavo volumes of "Miscellaneous Collections," and thirty octavo annual reports. These publications have been presented to the principal libraries of the Old and New World. It has especially advanced natural history and ethnology by the large number of specimens it has collected and distributed to foreign and domestic museums, and has been instrumental in widely diffusing a knowledge of the progress of science by its system of international exchanges between the United States and all other parts of the world. The system of "active operations," while advancing the interests of civilization generally, has been of importance to Washington

City in assisting to constitute it a centre of scientific and literary activity, and in co-operating with other institutions here established. Besides contributing to render the Library of Congress the first in the United States in the number and value of the books which it contains, it has deposited in the Department of Agriculture 30,000 specimens of plants, and many other objects connected with agriculture. It has also deposited with the Army Medical Museum a large collection of osteological specimens, and a series of skulls for the especial illustration of the craniology of the North American Continent. It has affiliated itself with the Corcoran Art Gallery, and deposited with that admirable institution the specimens of engravings received from its foreign correspondents, as well as a number of valuable pictures belonging to its collection.

From this sketch of the past and present condition of the Institution, it will, I think, be generally admitted that the trust has been faithfully administered, and that, although changes have been found necessary in the plan adopted by Congress, yet these have been only such as originated from the peculiar nature of the bequest and the difficulty, from *a priori* conceptions, of adopting the most efficient means of realizing the intentions of the donor.

The principal event of the year 1876 connected with the Institution is its display of specimens at the International Exposition in Philadelphia. It was stated in the last annual report that Congress had made an appropriation to enable the Institution to participate with the several Departments of the Government in the Centennial Exhibition. After careful consideration of the subject it was concluded that the part of the Government exhibition under the special charge of the Institution should consist of such articles as would illustrate (1) the character and operations of the Institution itself, (2) the mineral and animal resources, (3) the ethnology, and (4) the fishery industries of the United States. The responsibility of collecting and arranging these objects, as well as of representing the Institution at the Centennial Exhibition, was intrusted to Prof. S. F. Baird, assistant secretary of the Institution, who, with a corps of assistants principally engaged for the occasion, discharged the arduous duties assigned him in a highly satisfactory manner.

The part of the Government display under the auspices of the Institution has been pronounced by competent judges one of the most interesting and complete of the kind ever exhibited. The portion which illustrated the character and operations of the Institution embraced full sets of the three classes of its publications, a series of tables showing the extent and importance of the system of international exchange, and a number of large charts exhibiting the results of the system of meteorology founded by the Institution; that illustrating the mineral wealth of the country contained an extensive series of the ores of the precious and ordinary metals, with their products, the principal varieties of coal, the clays, marbles, slates, and other building materials, the several varieties of petroleum and coal-tar, &c., &c.—in short, a most extended collection of specimens of large size showing at one view the vast mineral resources of the United States, to which was added a variety of specimens to represent the different stages of the manufactured articles derived from the mineral kingdom. The display of the animal resources of the country was also extensive and various. It embraced all the species capable of economical application and such animals as were of special interest to the naturalist. These were represented by stuffed specimens, by life-size plaster models and by photographs. The industrial application of these animals was also exhibited as well as the apparatus by which they are pursued, captured and utilized. Among the larger mammals were well mounted specimens of those most valued for food, as the different kinds of deer, including the moose, elk and caribou, the musk-ox, and the buffalo; and the fur-bearing species were represented by bears, the grizzly, brown, black, and white; by the foxes, yellow, black, cross, gray, and kit; by wolves, fur-seals, sea-lions, sables, and minks; the oil-producing animals by whales, porpoises, and other cetaceans. Another part of the animal display embraced a series of specimens of animal food preserved by being dried, smoked, salted, pickled, and canned, together with representations of the various applications of the teeth, bones, horns, and scales; and, again, of articles used for clothing, as furs, leather, &c.

The ethnological branch of the Exposition was at the joint expense of the congressional appropriation for the Indian Bureau and that for the Smithsonian Institution. Special importance was attached to this section of the Exposition, and great exertion made to render it as complete as possible. To this end, agents were temporarily employed to obtain articles to illustrate the ethnology of portions of the country hitherto imperfectly known. The success of the enterprise was commensurate with the energy expended, and a more extensive and varied collection of articles was obtained to illustrate the past and present condition of the various native tribes of the American continent than was ever before exhibited. It consisted of a large number of the different varieties of specimens of the stone age from all parts of the continent and the West Indies, and a series of articles in use at the present time among the Indians, especially among tribes which have had but little connection with the white race. There were also exhibited numerous life-size figures to show every variety of Indian costume and personal decoration. Independent of the temporary interest which was subserved by this exhibition, the large collection of new articles has rendered an important service to the ethnology of the country, since these articles will be preserved for scientific study in the National Museum.

In addition to the foregoing, representatives, in plaster, papier-maché, and photography, of all the edible fishes of our coast were exhibited, in connection with the Smithsonian display, by the United States Fish

Commission, of which Professor Baird is the head. But for a full account of the part of the Centennial Exhibition known as the Government, or United States, exhibition, I must refer to the reports of Professor Baird in the appendix to my last and that of my present report.

The anticipations expressed in the last report in regard to the additions which would be made to the National Museum through the agency of the Centennial Exhibition have been fully realized. These additions consist of new specimens procured by the direct agency of the Institution, particularly for the exhibition; of donations from various States of the Union, from individuals, and especially from foreign exhibitors. These will require more than three times as much space for their display as was required by the previous collections of the Museum. To preserve and exhibit this increase, or to render it available for educational and scientific purposes, an additional building is imperatively demanded. The appropriation for erecting this building must be furnished by Congress, since the idea cannot for a moment be entertained of making it from the Smithson fund. Furthermore, the building should be an extension, as it were, of the present Smithsonian edifice, since if the National Museum is entirely transferred to another building the Institution would have left upon it, for support, a building erected from the income of the Smithson fund almost entirely for the accommodation of the Government collections and far too large and expensive for its own use. I beg leave, therefore, to repeat the suggestion made in my last report, that the Government be asked to take entire possession of the present edifice for the use of the Museum, to enlarge it so as to meet the present emergency, and to repay to the Institution at least a part of its cost; a portion of the sum thus repaid to be applied to providing other accommodations for the Institution in a building better adapted to its operations, and far less expensive in its maintenance; and the remainder to be added to the permanent fund for the increase of the power and efficiency of the establishment.

I may further be allowed to remark that the experience of the last year has strengthened my opinion as to the propriety of a separation of the Institution from the National Museum. The events of this period have proved that the Museum is destined to become an extensive establishment involving a large annual expenditure for its support and a variety of complex operations having no necessary connection with the plan adopted by the Institution for the "increase and diffusion of knowledge among men." Smithson gave *his own* name to the establishment which he founded, thereby indicating that he intended it as a monument to his memory, and in strict regard to this item of his will the endowment of his bequest should be administered *separate from all other funds*, and the *results achieved by it should be accredited to his name alone.* The Institution should not, therefore, be merged in an establishment of the Government, but should stand alone, free to the unobstructed observation of the whole world, and keep in perpetual remembrance the name of its generous founder. The functions of the Museum and of the Institution are entirely different. The object of the former is the establishment of a collection of specimens of nature and of art which shall exhibit the natural resources and industry of the country, or present at one view the materials essential to a condition of high civilization which exists in the different States of the American Union; to show the various processes of manufacture which have been adopted by us, as well as those used in other countries; in short, to form a great educational establishment, by means of which the inhabitants of our own country as well as those of foreign lands who visit our shores may be informed as to the means which exist in the United States for the enjoyment of human life in the present and their improvement in the future. The Smithsonian Institution, on the other hand, does not offer the results of its operations to the physical eye, but presents them to the mind in the form of new discoveries, derived from new investigations and an extended exchange of new ideas with all parts of the world.

It is the design of the Museum to continually increase its collection of material objects; of the Institution, to extend the bounds of human knowledge. The latter collects nothing for preservation of a material character. It is true it sends out explorers and makes large collections, but these are for distribution to museums, colleges and academies, or to all establishments in which they can be useful in the way of the extension of science or the advancement of education. Every civilized government of the world has its museum which it supports with a liberality commensurate with its intelligence and financial ability, while there is but *one Smithsonian Institution*—that is, an establishment having expressly for its object "the increase and diffusion of knowledge among men." The conception of such an institution—not a local establishment intended to improve the intellectual condition of any single city or any single nation, but that of mankind in general—was worthy of the mind of Smithson, and the intelligence and integrity of the United States are both involved in the proper administration of the trust, since the terms in which it was conveyed must be truly interpreted and the intention expressed rigidly carried out.

It has been supposed that the Institution has derived much benefit from its connection with the Museum in the way of adding to its popularity, but it should be recollected that the Institution is not a popular establishment and that it does not depend for its support upon public patronage, but that it is an establishment founded on the bequest of an *individual*, and that the very nature of its operations, involving study and investigation, is in a considerable degree incompatible with continued interruption from large numbers of visitors. So far from the Institution having derived advantage from the connection which has existed between it and the Museum, the latter has proved a serious obstacle in the way of the full development of the plan of the former in having absorbed, in the erection of the building and in the appropriations for the care of the specimens, at least one-half of the whole income of the Smithson fund. Furthermore, the Museum and also the Institution have now arrived at such a state of development that the two can scarcely be continued under one organization.

But the most objectionable result of the present connection of the two establishments is the necessity of the Institution appealing to Congress annually for appropriations for the support of the Museum, whereby, in the language of my last report, the Institution is presented to the world as a suppliant for perpetual aid, whereas, for carrying out the legitimate objects of the bequest, no annual appropriation is necessary from the public Treasury; for, although more than one-half of the whole income of the Smithson bequest has been devoted to a Museum and other local objects, it has succeeded, through its researches, publications, and exchanges, in establishing a reputation as extensive as civilization itself.

In this connection it may be stated that an important step has been made at the present session of Congress toward recognizing the National Museum as a separate establishment. In the language of the Act making appropriation for deficiencies, it is for the first time announced as an "appropriation for the National Museum in charge of the Smithsonian Institution."

Since the meeting of the board on the 24th instant, I have transmitted to the Senate and House of Representatives the resolutions adopted by the Regents relative to the necessity for the erection of an additional building in connection with the Institution, and have conferred with several members of Congress as to the probability of obtaining an appropriation for this purpose. These have given encouragement as to the probable appropriation of $250,000 for the erection of the proposed building,* but do not think that the proposition to purchase the Smithsonian building would at this time, on account of the condition of the Government finances, meet with favorable consideration. The proposition should, however, be kept before the public, and in due time, I doubt not, it will be adopted.

General M. C. Meigs, Quartermaster-General, United States Army, who had charge of the extension of the United States Capitol, and has had much experience in the construction of public buildings, has gratuitously furnished a plan for a new building for the Museum, and in addition generously offers his assistance in superintending its construction. This building will be of durable though inexpensive material, and expressly adapted to the uses for which it is designed. In its con-

*The bill making an appropriation of $250,000 for the erection of the building passed the Senate without opposition, but failed to receive consideration in the House because a favorable vote of two-thirds of the members present was required to bring it before that body.

struction care will be exercised not to sacrifice utility to architectural effect, but the fact will be kept in view that architecture is essentially a useful art, and that the mind receives pleasure and improvement from the contemplation of perfect adaptability no less than from imposing exterior effect.

The operations of the Institution during the past year, independent of those connected with the Centennial, have been carried on with unabated energy.

FINANCES.

I am happy to inform the Regents that the finances of the Institution are still in a favorable condition and that from the First National Bank has been received the last instalment of the money which was on deposit at the time of its suspension. The Institution has therefore lost nothing on this account, except the interest of the money which might have accrued from its investment.

The following is a statement of the condition of the fund at the beginning of the year 1877:

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, now valued at	42,000 00
Cash balance in United States Treasury at the beginning of the year 1877 for current expenses	21,029 18
Total Smithson funds January 11, 1877*	$714,029 18

* The date at which the settlement of the accounts for 1876 was made.

(For a detailed account of the expenditures, &c., see report of executive committee.)

From this it appears that the total fund, including the Virginia stock at its present value and the cash on hand at the end of the year, amounts to $714,029.18. The receipts during the year 1876 were $47,486.21, and the expenditures $46,978.21, leaving a balance of $508 to be added to the balance on hand at the beginning of 1876. The interest on the Hamilton bequest has been received to December 31, 1876, and, in accordance with the terms of the will, an appropriation was made from it for an archæological exploration in bone-caverns in the vicinity of Carlisle, Pa., the former residence of Mr. Hamilton. The final results will be given to the world accredited to James Hamilton, and in this way his name will be perpetuated with that of Smithson, and his donation serve as an example to be followed by others who may desire to benefit the world and live in the history of science long after their departure from this life.

The interest on the Virginia bonds received during the year was $2,907.75. The marketable value of this investment remains about the same as it was at the date of the last report.

A fact which has been omitted through inadvertence in previous reports should here be mentioned, that the Institution is greatly indebted to our highly esteemed fellow-citizen, W. W. Corcoran, esq., for valuable suggestions in its early financial history; and especially for the transferring to the Regents, at par, instead of at the market value, of $240,000 of United States bonds as a safe investment of the amount of accumulated interest devoted to the erection of the building.

PUBLICATIONS.

Since the reports of the Institution are separately distributed to many persons who have not ready access to the whole series, it is necessary in each succeeding one to repeat certain facts which may serve to give an idea of the general organization of the establishment. The following statement is therefore repeated:

The publications of the Institution are of three classes, viz, the CONTRIBUTIONS TO KNOWLEDGE, the MISCELLANEOUS COLLECTIONS, and the ANNUAL REPORTS. The first consists of memoirs containing positive additions to science resting on original research, and which are generally the result of investigations to which the Institution has, in some way, rendered assistance. The Miscellaneous Collections are composed of works intended to facilitate the study of various branches of natural history, meteorology, &c., and are principally designed to induce individuals to engage in these studies as specialties. The Annual Reports, besides an account of the operations, expenditures, and condition of the Institution, contain translations from works not generally accessible to American students, reports of lectures, extracts from correspondence, &c.

The following are the rules which have been adopted for the distribution of the several publications of the Institution:

1st. They are presented to learned societies of the first class which in return give complete series of their publications to the Institution.

2d. To libraries of the first class which give in exchange their catalogues and other publications, or an equivalent from their duplicate volumes.

3d. To colleges of the first class which furnish catalogues of their libraries and of their students, and all other publications relative to their organization and history.

4th. To States and Territories, provided they give in return copies of all documents published under their authority.

5th. To public libraries in this country, containing 15,000 volumes, especially if no other copies are given in the same place; and to smaller libraries where a large district would be otherwise unsupplied.

6th. To institutions devoted exclusively to the promotion of particular branches of knowledge are given such Smithsonian publications as relate to their respective objects.

7th. The Annual Reports are presented to the meteorological observers, to contributors of valuable material to the library or collections, and to persons engaged in special scientific research.

The distribution of the publications of the Institution is a matter which requires much care and judicious selection, the great object being to make known to the world the truths which may result from the expenditure of the Smithson fund. For this purpose the principal class of publications, namely, the Contributions, must be so distributed as to be accessible to the greatest number of readers, and this will evidently be to large central libraries.

The volumes of Contributions are presented on the express condition that, while they are carefully preserved, they shall be accessible at all times to students and others who may desire to consult them, and be returned to the Institution in case the establishments to which they are presented at any time cease to exist. These works, it must be recollected, are not of a popular character, but require profound study to fully understand them; they are, however, of importance to the professional teacher and the popular expounder of science. They contain materials from which general treatises on special subjects may be elaborated.

The publications of the Institution during the past year are mainly those described in previous reports and which have been in process of preparation for a series of years. They form two volumes of the Smithsonian Contributions to Knowledge, XX and XXI, made up of separate papers.

The *twentieth* volume of the Smithsonian Contributions to Knowledge consists of one memoir only, entitled, The Winds of the Globe, or the Laws of Atmospheric Circulation over the Surface of the Earth; by James Henry Coffin, LL.D., Professor of Mathematics and Astronomy in Lafayette College, Pennsylvania. The tables of this volume were completed after the author's decease, and the maps drawn by Selden Jennings Coffin, professor of mathematics in the same institution. There is added to the work a discussion and analysis of the tables and charts, by Dr. Alexander Woeikof, late secretary of the meteorological committee of the Imperial Geographical Society of Russia. This volume consists of 781 quarto pages, 2 wood-cuts, and 26 plates or charts. We consider it, perhaps, the most important contribution to knowledge which the Institution has given to the world. It presents a rich mine of information for the use of the meteorologist, the physical geographer, and the mariner, thus combining materials of abstract scientific interest with knowledge immediately applicable to the practical affairs of life.

The *twenty-first* volume of Contributions to Knowledge consists of the following articles, viz:

1. Statement and Exposition of Certain Harmonies of the Solar System. By Stephen Alexander, LL. D., Professor of Astronomy in the College of New Jersey. 104 pages, 20 wood-cuts.

2. On the General Integrals of Planetary Motion. By Simon Newcomb, Professor of Mathematics, United States Navy. 40 pages.

3. The Haidah Indians of Queen Charlotte's Island, British Columbia; with a brief description of their carvings, tattoo designs, &c. By James G. Swan, Port Townsend, Washington Territory. 22 pages, 7 plates.

4. Tables, Distribution, and Variations of the Atmospheric Temperature in the United States, and some adjacent parts of America. Collected by the Smithsonian Institution, and discussed under the direction of Joseph Henry, Secretary. By Charles A. Schott, Assistant, United States Coast Survey. 360 pages, 9 diagrams, 2 plates, 3 charts. The whole volume consists of 543 pages, and 41 illustrations.

The work on Temperature, as we have stated in previous reports, consists of the results of the discussion of all the existing material which could be collected of observations of temperature in the United States, illustrated with large maps and a number of wood-cuts. It is published separately and also as a part of the series of volumes of "Contributions." The compilation of the materials and their discussion were intrusted to Mr. Charles A. Schott, of the Coast Survey, assisted by a number of computers at the expense of the Smithson fund.

In previous reports mention has been made of an extensive publication in preparation for the Institution, on the Antiquities of Tennessee, by Dr. Joseph Jones, of the medical department of the University of Louisiana, at New Orleans. Some years ago a small appropriation was made by the Institution to assist this gentleman in his exploration. He pursued his investigations with great ardor and success. In presenting an outline of his explorations he states that an effort was made to accomplish two results: first, the accurate description of the aboriginal remains, and, second, the collection and classification of such facts as bore on their obscure history. The work when first submitted to the Institution was found to contain more historical and bibliographical matter selected from known authorities than could properly be considered contributions to existing knowledge, and it was therefore returned to the author for revision and abridgment. The omissions and modifications desired having been made, the work has been published during the past year. Some idea of its character may be obtained from the following titles of the chapters:

Burial caves.

Modes of burial practiced by the aborigines of America.

Mounds, fortifications, and earth-works.

Earth-works on the Big Harpeth River.

Earth-works on the West Harpeth and Big Harpeth Rivers.

The stone fort, and other aboriginal remains.

Relics from the mounds and stone graves.

General conclusions.

It forms a volume of 181 quarto pages with 85 wood-cuts and a very full index prepared by Prof. O. T. Mason. It will constitute a part of the twenty-second volume of the Contributions to Knowledge.

Another quarto work published during the year, and which was prepared especially for distribution at the Centennial Exposition, is that on the Archæological Collections of the United States National Museum in charge of the Smithsonian Institution, by Prof. Charles Rau. This work consists of 118 quarto pages, illustrated by 340 wood-cuts, and an account of it will be found under the head of Ethnology.

Miscellaneous collections.—In previous reports a work was described of which the first part had been published, entitled "The Constants of Nature," compiled gratuitously for the Institution by Prof. F. W. Clarke. This part was on the specific gravity, boiling and melting point and chemical formula of 2,572 distinct bodies, including over 5,000 determinations. During the past year a supplement to this part has been published consisting of the determinations of specific gravities, boiling-points and melting-points made since 1873. In it the determinations are given for nearly 700 substances, of which at least 400 are new. It is embraced in 61 octavo pages.

Part II of the same general work has also been published during the past year. It is entitled "A table of specific heats for solids and liquids," consisting of 58 octavo pages, including 410 substances.

Part III has also been printed, consisting of "Tables of expansion by heat for solids and liquids." It gives data for the expansion of about 350 different substances, no liquid mixtures or solutions, however, being included. It occupies 57 octavo pages. This work has been much called for by practical chemists and physicists. It will be continued from time to time as the author, amid other professional engagements in the University of Cincinnati, can find leisure to select and verify the materials.

In the year 1875 another series of publications was commenced which forms a part of the Miscellaneous Collections. It is entitled "The Bulletins of the National Museum," and is intended to illustrate the collections of natural history and ethnology belonging to the United States, of which the Smithsonian Institution is the custodian. Six numbers of these Bulletins have been published. They are prepared at the request of the Institution by different individuals, and are printed by the authority of the Secretary of the Interior at the Government Printing-Office.

The following is a list of these Bulletins:

I. Check-list of North American Batrachia and Reptilia; with a systematic list of the higher groups, and an essay on geographical distribution, based on the specimens contained in the United States National Museum. By Edward D. Cope. 1875. 8vo, 108 pp.

II. Contributions to the Natural History of Kerguelen Island, made in connection with the American Transit of Venus Expedition, 1874–'75. By J. H. Kidder, M. D., U. S. N. Part I, Ornithology, edited by Dr. Elliott Coues, U. S. A. 1875. 8vo, 62 pp.

III. Part II of the foregoing, consisting of Oology, Botany, Geology, Mammals, Fish, Mollusks, Insects, Crustaceans, Annelids, Echinoderms, Anthozoa, Study of Chiornis Minor. Prepared by J. H. Kidder, E. Coues, Asa Gray, F. M. Endlich, Th. Gill, W. H. Dall, C. R. Ostensacken, H. A. Hagen, S. I. Smith, A. E. Verrill, and S. F. Clark. 1876. 8vo, 124 pp.

IV. Birds of Southwestern Mexico, collected by Francis E. Sumichrast, for the United States National Museum. Prepared by George N. Lawrence. 1876. 56 pp.

V. Catalogue of the Fishes of the Bermudas, based chiefly upon the collections of the United States National Museum. By G. Brown Goode, assistant curator United States National Museum. 1876. 8vo, 84 pp.

VI. Classification of the collection to illustrate the animal resources of the United States. A list of substances derived from the animal kingdom, with synopsis of the useful and injurious animals, and a classification of the methods of capture and utilization. By G. Brown Goode, assistant curator United States National Museum. 1876. 8vo, 140 pp.

An account of the first two of the Bulletins was given in the last annual report.

The third number of the series, that on the natural history of Kerguelen Island, by Dr. J. H. Kidder, United States Navy, embodies the result of the examination of the eggs, the identification of the plants, fishes, mollusks, insects, &c., of the region. It also contains a brief description of the collections of Surgeon Kershner, of the United States Navy, in the Chatham and Auckland Islands, and in New Zealand, and of Mr. I. Russell in the latter place.

The botany of Kerguelen Island had previously been very thoroughly studied by Dr. J. D. Hooker in connection with Sir James Clarke Ross's Antarctic Expedition, (1839–'41.) A number of new phanerogams, ferns, sea-plants, and lichens have been added to the list.

The zoölogical collections, though comparatively small, contain an unusual number of new genera and species, especially among the mollusca, insects, crustacea, echinoderms, &c., descriptions of which have been furnished to Dr. Kidder by Professors Verrill, S. I. Smith, Dall, Ostensacken, and Hagen.

The Bulletin concludes with a study of *Chionis minor*, a unique and little-known bird, with an attempt to establish its proper position in classification.

Bulletin No. 4, the catalogue of birds collected by Prof. Francis Sumichrast in Southwestern Mexico, is a scientific account of the collection made in accordance with an arrangement between the Smithsonian Institution and Professor Sumichrast for an extended exploration of the Pacific side of the Isthmus of Tehuantepec for the purpose of procuring specimens of its natural history. During the past four years, four instalments of birds have been received and examined by Mr. Lawrence, containing 321 species, represented by more than 1,700 specimens, all of a remarkably fine character, and bearing testimony to Professor Sumichrast's efficiency as an industrious and energetic collector, while the character of the many valuable notes he has contributed manifest his minuteness and intelligence as an observer.

From this exploration it appears that the region of the Pacific is comparatively much poorer in birds than that of the Atlantic. This is attributed to the extreme dryness of the soil, to the scarcity of vegetation and of insect life, and to the duration of the winds from the northeast and southwest, which there prevail with great violence. The contraction of the American continent between the ninety-fourth and ninety-fifth degrees of longitude west from Greenwich, forms what is called, improperly perhaps, the Isthmus of Tehuantepec. In a physical point of view, it may be considered as divided into three parts: first, an eastern, extending from the Gulf of Mexico to the Puerta; second, a central, from the Puerta to the Chivela; and, third, a western, from the Chivela to the Pacific. The eastern part has its largest portion covered with thick and damp forests, vegetation which rivals the greatest beauties of the tropics. The central region presents an undulating surface embossed with innumerable hills which gradually unite on the western side with the mountains of the Sierras. Although watered by numerous streams, it presents but a scanty vegetation, essentially characterized by oaks on one side and palm-trees on the other. The western division, or plains of the Pacific, is very dry, and presents a striking contrast to the rich plains on the Atlantic slope. The number of animal forms, as well as the vegetable, decreases perceptibly in proportion as we advance from the Atlantic to the Pacific. It is worthy of note that while the species belonging to the western province seldom, if ever, find their way to the eastern division, those, on the contrary, in the latter province, spread to within a short distance of the shores of the Pacific. The difference in the elevation of the ground which exerts in Mexico such a great influence over the geographical distribution of animal species, exists only in a slight degree in the Isthmus of Tehuantepec, the highest point of the territory, not being elevated more than from 500 to 2,800 feet above the level of the sea.

The fifth bulletin, a "Catalogue of the Fishes of the Bermudas," is based chiefly upon collections in the United States National Museum, made and described by G. Brown Goode.

A visit to the Bermudas during the months of February and March, 1872, afforded the author opportunities for collecting the notes and specimens upon which this paper is based. At the time of his visit only seven species of fishes had been recorded from this locality, and the only authentic information regarding the fish-fauna was contained in one short chapter of a work by John Matthew Jones, of England. In the present list, Mr. Goode enumerates seventy-five species, most of which were personally observed.

Bulletin No. 6 consists of a tabular classification prepared by Professor Goode, to facilitate the work of collecting and arranging the materials gathered by the Institution for the International Exhibition, to illustrate the resources of the United States as derived from the animal kingdom. With a view to its future use in the classification of the articles of the kind which it includes, it is presented in a permanent form as a part of the Miscellaneous Collections. It forms a pamphlet of 140 octavo pages, of which the following are the several divisions: The first group, section A, is an index of the whole series, including all North American animals which are directly beneficial or injurious to man. Section B embraces all instruments and methods employed by the hunters, trappers, and fishermen of North America, aboriginal and civilized. It is a monograph of all matters relating to the chase and fisheries of the country. Section C includes all methods of utilizing animal products. Section D presents a list of all useful substances derived from the animal kingdom, and section E all articles illustrating the culture and protection of useful animals. Though this work was hurriedly prepared for use at the Centennial Exhibition, and is necessarily incomplete, yet it will serve as a basis for other attempts of a similar character, and will be of especial use in making preparation for future International Exhibitions.

Centennial Outline Map of the United States and other portions of North America.—In order to serve as a basis for showing the larger features of the physical geography, and to present graphically any special statistics of the United States to accompany the exhibits from the Smithsonian Institution at the International Exhibition of 1876, it was deemed desirable to have constructed an outline map on a scale sufficiently large for that purpose. The design and construction of this map were intrusted to Mr. W. L. Nicholson, topographer of the Post-Office Department, and from the drawings prepared under his care a number of prints were made by lithograph transfer. The map is on a scale of 16 miles to the inch, (1 : 1,013,760,) in 20 sheets, covering, when mounted, an area of 16¾ feet long, (horizontally,) by 15 feet wide, (vertically,) extending from the southern shores of Lake Winnepeg and Hudson's Bay to the parallel of 15° north latitude, taking in the whole of the Gulf of Mexico, Yucatan, and the larger West India Islands. From east to west it includes parts of Nova Scotia and of Vancouver Island, the Territory of Alaska being shown, on a smaller scale, detached, in a vacant corner of the map. The meridians and parallels were laid down from the polyconic-projection tables of the United States Coast Survey Office. The details are restricted to the more general topographical (and political) features—the shore-lines of the oceans and great lakes, the principal rivers, the State and international boundaries, and a few of the larger cities, the mountain-topography being omitted, as one of the desiderata for additions to such a map of this continent.

The original construction and the printing of this map were undertaken by the Smithsonian Institution, but, as an offset toward the reimbursement of this expense, propositions were made and accepted from several of the subcommissions of the United States executive departments exhibiting at Philadelphia for the purchase of a limited number of copies of the map. Under these arrangements, the Agricultural Department made use of a series of six of these maps, exhibiting by colors, in a very effective manner, statistics of the value of farm-lands, wages of farm-labor, areas of woodland, products of sugar-crops, of textile fibers, and of fruits. The Light-House Board employed one for showing the sites of and the relative orders of all the light-houses along the sea-coast, the great lakes, and the Mississippi, Missouri, and Ohio Rivers. The Post-Office Department made use of one to show the railway mail-service of the United States. Various bureaus of the Department of the Interior, including the Census, Education, and Geological Survey of the Territories, used several sets of the same.

The Smithsonian Institution exhibited four of these maps for presenting the results of the meteorological discussions of rain-fall and of temperature over the United States in the summer and winter months. These were enlargements from the maps accompanying the publications of the Smithsonian Institution. On these four maps an attempt was made, by the addition of the greater mountain chains, to give a coincident view of their relation to the great climatic elements.

A fifth set of the sheets was used for representing the geology of the United States and Territories.

There now remain on hand several sets of the original prints of this large outline map, available for purposes similiar to the foregoing, and which it is proposed to dispose of to institutions or associations willing, by a small proportionate outlay, to aid in the re-imbursement of the original expenses.

Annual report.—The annual report of the operations of the Institution for the year 1875 was presented to Congress on the 7th of April, 1876, but the extra copies ordered as usual were not delivered to the Institution until December, and their distribution has therefore only just now commenced. An edition of 10,500 copies was printed, 1,000 for the use of the Senate, 2,000 for the House of Representatives, and 7,500 for the Institution. The appendix to the report contains translations of Arago's eulogy on Volta; DeCandolle on the probable future of the human race; the annual report for 1873–'74 on the transactions of the Geneva Society of Physics and Natural History; a lecture on the past and future of geology, by Prof. Joseph Prestwich, of England; a report on the diminution of the water of rivers and streams, by a committee of the Royal Academy of Vienna; an original communication on the refraction of sound, by Wm. B. Taylor, of Washington; a letter by Professor Henry on the organization of local scientific societies, intended to furnish an answer to numerous letters addressed to the Institution on this subject; a translation of a proposed international code of symbols for charts of prehistoric archæology, by Profs. Mortillet and Chantre; an article on characteristics pertaining to ancient man in Michigan, by Henry Gillman; and a memoir on the stone-age in New Jersey, by Dr. C. C. Abbott.

RESEARCHES.

It has been stated in previous reports that an annual appropriation was made for several years to enable Professor Newcomb, of the National Observatory, to employ accountants for the reduction of the mathematical expressions of the orbits of the planets Uranus and Neptune to numerical tabular results.

Although the representation of the observations of Uranus by the tables presented to the Smithsonian Institution four years ago, was regarded by astronomers generally as highly satisfactory, it was not so considered by the author, owing to the systematic character of the minute discrepancies. He therefore desired to ascertain whether these discrepancies arose from errors in the computation of the perturbations of Uranus, and, if not, whether they could be due to the action of an ultra-Neptunian planet. The first step in the investigation was to have a complete duplicate computation of the perturbations from 1753 until the present time, by the method of mechanical quadratures, with which to compare the results computed from the tables. An appropriation having been made by the Institution for this investigation, it has been found that there is a small discrepancy between the two sets of results, the cause of which has not yet been ascertained.

If it is found on further examination that there is really a discrepancy between the observations of Uranus and its motion as computed from the theory of gravitation, it will be considered that the chance of the discrepancy being due to an ultra-Neptunian planet is sufficient to justify the continuance of the work.

Professor Newcomb remarks that the problem now before us is vastly more difficult than that with which Le Verrier had to deal. When Le Verrier had completed the determination of the motions of Uranus, taking into account the action of Neptune, he considered the representation of the observations by theory highly satisfactory. But the outstanding differences were far larger than those with which we are now occupied.

In regard to the computations of the comet of short period mentioned in the last report, we have nothing further to report at present, the work having been suspended for a time on account of the transfer of Professor Stone from the National Observatory to the Cincinnati observatory, and the consequent absorption of his time in preparing for his new duties.

A small appropriation has also been made for a series of physiological observations on the temperature of the human body under certain abnormal conditions, by Prof. H. C. Wood, jr., and Dr. Horace Hare, of Philadelphia. These observations are in progress, and it is thought the results of the investigation will be ready for publication in the next annual report. They relate especially to the subject of animal heat, the mode of its production, and its relation to pathological and normal functions. The first question to be investigated is whether ordinary fever is due to an increased production or retention of heat. A series of analytical experiments as to the amount of carbonic acid given off by the animal during the normal and the febrile state, also the amount of excretions from the kidneys, will be made, and a determination as to whether the depression of temperature, caused by ammonia, section of the spine, injuries, &c., is due to a diminished production or increased loss of heat; also whether the paralytic fever observed in connection with certain nerve sections is always caused by such sections, whether it is induced by an increase in the production of heat, or by its retention; and finally, how the nervous system acts in the regulation of the calorific function.

METEOROLOGY.

The Institution has continued the reduction and discussion of the large amount of meteorological material which it collected during the twenty years of its system of observations. The miscellaneous work by the computers of the Institution during the year 1876, is as follows:

1. The temperature-observations for the years 1871, '72, '73, have been

reduced and partly tabulated, thus closing the series conducted by the Institution relative to temperature.

2. The temperature and rain-fall observations made at a large number of stations in British North America have been tabulated to the end of the year 1874. This was a special matter undertaken to facilitate and extend the rain-fall discussion.

3. A number of averages have been computed and the work continued relative to the publication of a second edition of the memoir on the rainfall of the United States, which will embrace additional material.

4. Meteorological information has been furnished in many instances to individuals making application therefor, they bearing the expense of the clerical labor involved in the copying.

To complete the reduction and discussion of the system of meteorology conducted by the Institution, there remain the observations relative to the pressure of the atmosphere, and also those relative to moisture, thunder-storms, and casual phenomena. These will be taken up during 1877.

TELEGRAPHIC ANNOUNCEMENT OF ASTRONOMICAL DISCOVERIES.

The arrangement which was concluded between the Smithsonian Institution and the Atlantic cable companies in 1873, by which free telegraphic transmission of astronomical discoveries was granted between Europe and America, has been continued during the past year.

The following is a list of the small planetoidal bodies discovered in 1876, the most of which discoveries were announced through this Institution:

No.	Name.	Date of discovery.	Discoverer.	Place of discovery.	Mean distance.*
158	Coronis	January 4	Knorre	Berlin	3.00
159	Emelia	January 26	Paul Henry	Paris	3.13
160	Una	February 20	Peters	Clinton	2.75
161	Athor	April 16	Watson	Ann Arbor	2.38
162	Laurentia	April 21	Pros. Henry	Paris	3.02
163	Erigone	April 26	Perrotin	Toulouse	2.35
164	Eva	July 12	Paul Henry	Paris	2.55
165	Loreley	August 9	Peters	Clinton	3.13
166	Rhodope	August 15	Peters	....do	2.72
167	Urda	August 28	Peters	....do	3.22
168	Sibylla	September 28	Watson	Ann Arbor	3.38
169	Zelia	September 28	Pros. Henry	Paris	2.36

A stellar outburst in the constellation of the "Swan" was observed November 24, 1876, by Dr. Schmidt, at Athens; a phenomenon similar to the remarkable stellar outburst which occurred in the "Northern Crown" in May, 1866, though not so brilliant, as it did not apparently exceed the light of a star of the third magnitude at its greatest brightness. At the close of the year it had dwindled to the lowest visible magnitude.

* The figures in the last column of the table represent the mean distances of the several bodies from the sun, that of the earth being taken as unity.

CORRESPONDENCE.

The correspondence of the Institution during the past year, especially on account of the Centennial Exhibition, was very largely increased, and has formed no inconsiderable part of the labors of the officers. The usual number of inquiries have been made as to the name and character of specimens of natural history, mineralogy, &c. The number of scientific problems received for solution has not been diminished. Several elaborate treatises have been submitted to the Institution for examination, purporting to be explanations of the theory of gravitation, and other extended generalizations of natural phenomena. As the theory of gravitation is a prominent subject of investigation by those who are interested in scientific speculations, we would direct attention to a paper, published in the appendix to this report, prepared for the Institution by Mr. William B. Taylor, of Washington, giving a history, with comments, of all the attempts which have been made since the discoveries of Newton to the present time to refer the phenomena of gravitation to some other cause than that of action at a distance. This elaborate paper will exhibit the difficulties of the problem which those who endeavor to solve it have to contend with, as well as the entire failure of all the attempts which have been made and the probable result of all that will be hereafter essayed in regard to it.

Among the subjects to which attention has been called by foreign correspondents is that of the organization of a society, under the auspices of the King of Belgium, at Brussels, for a thorough exploration of the African continent, the final object of which being the suppression of the slave-trade, the opening of the country to foreign commerce, and its advancement in civilization. To this enterprise the attention of all the geographical societies of the world is called, and their co-operation solicited. It is proposed to run lines of survey across the continent from east to west and from north to south, establishing depots at intervals for the accumulation of articles of commerce and the supply of the explorers. This is truly an enterprise worthy of the present age, since its object is to open, for the uses of civilized man, a portion of the earth richly endowed with the means of the support and the enjoyment of human life, now almost a waste, or only sparsely inhabited by barbarian tribes. It is a work to which the attention of our educated citizens of pure African descent should be directed, as opening a field of unparalleled usefulness in the way of advancing the civilization of the world, and it is one to which they are especially adapted, since, in a letter from Professor Edw. D. Blyden, of Liberia College, published in the appendix to the Smithsonian Report for 1870, it is shown that only individuals of pure African blood are fully fitted for withstanding the peculiar influence of the climate.

EXCHANGES.

The operations of this part of the general system of labor of the Institution have assumed a magnitude during the past year far greater than that of any previous year since its first adoption. This has arisen from the fact that we have presented to foreign libraries, especially those of Australia and New Zealand, a large number of sets of the publications of the Institution, and also those of the publications of the Government entrusted to the Institution for distribution.

During the past year 4,853 packages, each containing several articles, have been received from abroad for distribution to institutions and individuals in this country.

Three hundred and twenty-three boxes, averaging 7 cubic feet each, with a total weight of 80,000 pounds, were sent abroad by the Institution during the year. The total number of separate parcels contained in these boxes was about 13,000.

As an evidence of the high estimation in which this branch of the operations of the Institution is regarded, as well as to give proper credit to the parties who have transmitted free of cost the packages of the Institution, we reprint, as usual, the following list of their names:

Cunard Steamship Company.
Anchor Steamship Company.
Pacific Mail Steamship Company.
Panama Railroad Company.
Pacific Steam Navigation Company.
New York and Mexico Steamship Company.
New York and Brazil Steamship Company.
North German Lloyd Steamship Company.
Hamburg American Packet Company.
French Transatlantic Company.
North Baltic Lloyd Steamship Company.
Inman Steamship Company.

The special thanks of the Institution are again tendered to the above-mentioned companies for their enlightened liberality.

We may also mention as an evidence of the high appreciation of the character of the Smithsonian exchanges that the packages bearing the marks of the Institution are admitted free of duty and without examination into all foreign ports.

The following are the principal foreign agencies of reception and distribution of the Smithsonian exchanges:

London, William Wesley, 28 Essex street, Strand.
Paris, G. Bossange, 16 Rue du 4 Septembre.
Leipsic, Dr. Felix Flügel, 49 Sidonien Strasse.
St. Petersburg, L. Watkins & Co., 10 Admiralty Place.
Amsterdam, Frederick Müller, Heerengracht KK. No. 130.
Milan, U. Hoepli, 591 Galeria Cristoforia.
Harlem, Professor von Baumhauer.
Christiania, Royal University of Norway.
Stockholm, Royal Swedish Academy of Sciences.
Copenhagen, Royal Danish Society.
Lisbon, Royal Academy of Sciences.
Madrid, Royal Academy of Sciences.

Havana, Dr. Felipe Poey.
Santiago, University of Chili.
Mexico, Mexican Society of Geography and Statistics.
Montreal, Geological Survey of Canada.

The packages of the Institution for the West Indies have been kindly forwarded by Mr. Thomas Bland, of New York, and those for Turkey, by Messrs. Chrysoveloni & Co., of 5 Fenwick street, Liverpool, England; and some other points in the East, by the American Board of Commissioners for Foreign Missions, Boston.

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	Italy	181
Argentine Republic	13	Japan	4
Australia	30	Java	5
Belgium	111	Liberia	1
Bolivia	1	Mauritius	3
Brazil	9	Mexico	15
British America	27	New Zealand	15
British Guiana	3	Norway	25
Cape Colony	4	Peru	3
Central America	2	Philippine Islands	3
Chili	8	Polynesia	2
China	1	Portugal	23
Colombia	3	Russia	162
Denmark	28	Spain	18
Dutch Guiana	1	St. Helena	2
Ecuador	1	Sweden	22
Egypt	8	Switzerland	70
France	324	Syria	1
Germany	646	Turkey	11
Great Britain and Ireland	368	Venezuela	2
Greece	8	West Indies	7
Holland	65	General	7
Iceland	2		
India	29	Total	2,275

Statistics of exchanges sent during the last eight years.

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

To facilitate the business of the exchanges, the following rules have been adopted:

1. Every package, without exception, must be enveloped in strong paper, and secured so as to bear separate transportation by express or otherwise.

2. The address of the Institution or individual, for whom the package

is intended, must be written legibly on the cover, and the name of the sender on one corner of the same.

3. No single package must exceed half of a cubic foot in bulk.

3. A detailed list of addresses of all the parcels sent, with their contents, must accompany them.

5. No letter or other communication can be allowed in the parcel, excepting such as relates exclusively to the contents of the package.

6. All packages must be delivered in Washington free of freight and other expenses.

7. Every parcel should contain a blank acknowledgment, to be signed and returned, either through the agent of the Institution, or, what is still better, through the mail, to the sender.

Should returns be desired for what is sent, the fact should be explicitly stated on the list of the contents of the package. Much disappointment is frequently expressed at the absence of any return in kind for transmissions; but unless these are specifically asked for, they will fail in many instances to be made. It will facilitate the labors of the Institution very much if the number corresponding to the several addresses in the Smithsonian printed catalogue be marked on the face of each parcel; and for this purpose a copy of the catalogue will be forwarded to all who apply for it.

Specimens of natural history will not be received for transmission unless with a previous understanding as to their character and bulk.

8. Unless all these conditions are complied with, the parcels will not be forwarded from the Institution; and, on the failure to comply with the first and second conditions, will be returned to the sender for correction.

Exchange of Government documents.—In the last report a full account was given of the system adopted for carrying out the law relative to the exchange of the official publications of United States Government for those of foreign nations. In accordance with this system, during the past year 120 boxes of documents were forwarded, the following being a list of the distribution:

International exchange of Government publications in 1876.

Sent to—	Boxes.	Sent to—	Boxes.
Queensland	7	Germany	3
Victoria	7	Saxony	5
South Australia	7	England	5
New Zealand	7	Spain	5
New South Wales	7	Turkey	1
Tasmania	7	Holland	1
Switzerland	7	Belgium	1
Sweden	7	Portugal	1
Scotland	7	Ottawa	1
Buenos Ayres	7	Ontario	1
Hayti	6	Mexico	1
Venezuela	6	Brazil	1
Norway	5	Chili	1
Prussia	5	Japan	1

The expense of boxing, packing, transporting, and paying of agents in connection with the transmission of these sets of Government documents, amounting to $857.50, was advanced by the Institution, with the expectation that it would be repaid from an appropriation for the Library of Congress; but when the account was presented we were informed that, in consequence of the reduction of the appropriations at the last session of Congress, there were no funds available for the purpose. We have, therefore, requested the Library Committee of Congress to procure the insertion of an item in the deficiency bill to re-imburse the Institution for the amount advanced, and also to defray the cost of the necessary expenses of the system of exchange for the ensuing six months.

LIBRARY.

The library of the Institution, as has been stated in previous reports, has been placed on deposit in the Library of Congress under the direction of Mr. A. R. Spofford, librarian.

The following is a statement of the books, maps and charts received by the Smithsonian Institution in 1876 and transferred to the Capitol:

Volumes:		
Octavo, or less	756	
Quarto, or larger	261	
		1,017
Parts of volumes:		
Octavo, or less	2,047	
Quarto, or larger	2,268	
		4,315
Pamphlets:		
Octavo, or less	1,530	
Quarto, or larger	348	
		1,878
Maps and charts		375
Total		7,585

The articles received at the Institution are recorded in a book prepared for that purpose and afterwards transferred to the Library of Congress. Much use is made of the books of the Institution which are in the Library of Congress as well as those of the latter library by the collaborators of the Institution.

Among the principal donations received in 1876 are the following:

From the director-general of the Royal Collections of Art and Science, Dresden: "Monumente des Mittelalters und der Renaissance aus dem sächsischen Erzgebirge, die Klosterkirche Zchillen, jetzt Wechselburg und die Rochlitzer Kunigunden-Kirche. 50 Blatt gross folio, photographische Aufnahmen und Schnellpressen Lichtdruck von Römmler & Jonas, Dresden, unter artistischer Leitung von Carl Andreae."

Dresden, 1875. "Gravirte und geätzte Ornamente von Gegenständen des k. Historischen Museums und der Kunstgewerblichen Ausstellung zu Dresden vom Jahre 1875." Parts i and ii, Dresden, 1876. Folio. "Archiv für Literaturgeschichte." Vols i, v, 1–3. Leipzig, 1870–1876, 8vo. "Mittheilungen aus dem k. Zoologischen Museum zu Dresden." Part 1, Dresden, 1875, 4to, and various pamphlets.

From the Royal Historical Academy, Madrid: Coleccion de Documentos inéditos para la Historia de España. Vols. xxi, lix. Madrid, 1852–1873, 8vo, and Historia de Felipe III. Vols. I, II, Madrid, 1875, 8vo.

From the Ambrosian Library, Milan: "Translatio Lyra Pescitto Veteris Testamenti ex Codice Ambrosiano." Vol. I, Part 1. Mediolani, 1876. Folio.

From the Austro-Hungarian War Department, Vienna: "General Karte von Bosnien, der Herzegovina, von Serbien und Montenegro." 120 sheets.

From the Icelandic Literary Society, Reykiavik, Iceland: Skirnir, 1875, Copenhagen, 8vo. Skyrslur og Reikningar, 1874–1875, Copenhagen, 1875, 8vo. Frjeltir fra Islandai, 1874. Reykiavik, 8vo. Report on the Icelandic Literary Society, Copenhagen, 1872, 8vo.

From Mr. James L. Bowes, Liverpool: Keramic Art of Japan, illustrated. Parts iii, iv. London and Liverpool, 1876. Folio.

From the British Museum, London: The Cuneiform Inscriptions of Western Asia. Vol. iv. London, 1875. Folio. Catalogue of Birds. Vol. ii. 1875, 8vo. Catalogue of Additional MSS. 1854–1860. 1875. 8vo. Catalogue of Spanish MSS. Vol. i. 1875. 8vo. Catalogue of Oriental Coins. Vol. 1. 1875. 8vo.

From the Ministry of the Interior, Topographical and Hydrographical Division, Christiania, Norway: Aarbog for Handels Marinen, 1870–1875, 11 parts, Kristiania, 8vo. Den Norske Lods, vols. i and viii, Kristiania, 1870, 1871, 8vo., and 36 charts.

From the University of Chile, Santiago: Anales, vols. xlv and xlvi, Santiago, 1873, 1874, 8vo. Twenty-one volumes of government documents, 1874, 1875, 4to.

From the Society of Natural History, Madrid, Spain: Anales, vols. i–v, Madrid, 1872–1876, 8vo.

From Dr. Otto Ule, Halle, Saxony: Die Natur, vols. xi, xii, xvii, xix–xxiii. New series, i, ii, Halle, 1862–1876, 4to.

From the Royal Academy of Science, Letters, and Arts, Modena, Italy: Memorie, vols. xiii–xvi, Modena, 1872–1875, 4to.—33 dissertations and discourses.

Die Astronomisch geodätischen Arbeiten des K. K. Militär, Geographischen Instituts in Wien. III. Vienna, 1875. 4to. General Karte von Central Asien. Blatt 1–12. Special Karte im Maastabe 1, 75,000. 22 parts.

From the Geographical Establishment, Brussels, Belgium: Nouveau

Plan Hypsométrique de Bruxelles et des Environs, 33 parts. Carte des Chemins de Fer de la Belgique, 1876. Carte des Chemins de Fer de l'Europe Centrale. Mirror d'Uranie d'apres l'Anglais d'Elton. Carte Générale de la Palestine. Atlas Universel de Geographie, composée de 20 belles cartes.

From the Observatory of the Roman College, Rome, Italy: Bulletino Meteorologico, 1863–1875, 10 vols., 4to, and 36 astronomical pamphlets.

From the Royal Swedish Academy of Sciences, Stockholm: Handlingar Ny. Folja. Vols. x-xii, 1872–1875. 4to. Bihung, vols. i-iii, 1872–1776. 8vo. Ofversigt. Vols. xxviii–xxxii, 1872–1876, and 8 parts of volumes and pamphlets.

From the Russian Government, Ministry of War, St. Petersburg: Eestniah Osadie Straasbourgah. Vols. i and ii. St. Petersburg, 1874, 1875. 8vo. Artillerysky Zhurual, 61 parts. Eengenneerie Zhurual, 29 parts. Oreyeyuyy Zboruik, 22 parts, and Voennoe Zboruik, 6 parts.

From the Hungarian Academy of Science, Buda-Pesth: Publications of the Academy, 38 vols. and 133 parts of volumes. Buda-Pesth, 1875–1876, 4to. and 8vo.

From the Board of Admiralty, London: Tide-tables for the British and Irish ports, 1876, 8vo. Remarks on Davis Straits, Baffin's Bay, &c., 1875, 8vo. Lights, 1876, 10 in number, and 32 charts published by the Hydrographic Office.

From the Royal Library, Stockholm: Government documents, 25 volumes, 1876, 4to.

From the Imperial Medico-Chirurgical Academy, St. Petersburg: 31 Inaugural dissertations for 1875.

From the Universities of Dorpat, Helsingfors, Berlin, Bonn, Buda-Pesth, Erlangen, Göttingen, Greifswald, Halle, Heidelberg, Leipzig, Marburg, Tübingen, Bern, Zürich, Louvain, and from the Royal High-School, Utrecht: Inaugural dissertations for 1875.

From the Library of Parliament, Ottawa, Canada: 21 volumes, and from the Parliament of Ontario, Toronto, 10 volumes government documents.

From the State Library of Vermont: 6 volumes documents.

From the State Library of Ohio: 10 volumes documents.

ETHNOLOGY.

The Institution during the past year has, as usual, given special attention to ethnology, and has directed investigations to be made in all cases where information has been received of the existence of mounds, shell-heaps, &c. The subject, however, has received a special impetus through the Centennial appropriation of Congress, circulars having been distributed to the correspondents of the Institution requesting aid in collecting specimens and in giving information as to the existence of particular collections. By this means and through the agency of the United States Indian Bureau a very large addition has been made to the collection of ancient implements as well as to that of those used by Indians of the present day. It was stated in the last report that the services of Charles Rau, a well known ethnologist, had been engaged to classify and arrange the collection in the National Museum and to prepare a descriptive catalogue for publication. This work he has accomplished in connection with the Centennial Exhibition, and although the catalogue is not entirely exhaustive it will serve to show what ample material has been obtained by the Smithsonian Institution for the study of North American archæology. The following is an account of the work in question:

In the introduction the author speaks of the system adopted by him in arranging the Smithsonian collections illustrative of North American archæology and ethnology. The *archæological* series comprises objects supposed to belong to times antecedent to the European occupation, and which, therefore, are thought to exhibit aboriginal art unmodified by contact with the whites. These relics, consisting of chipped and ground stone, of copper, bone, horn, shell, clay, and, to a small extent, of wood, were found in mounds and other burial-places of early date, in caves and in the shell-heaps met with along the coasts of North America. The second, or more strictly *ethnological*, series, a description of which is not attempted in the present volume, consists of articles obtained from existing native tribes by private explorations, as well as by expeditions undertaken by order of the United States Government, and contains almost every object tending to illustrate the domestic life, hunting, fishing, game, warfare, navigation, traveling by land—in short, every phase of the existence of these tribes that can be represented by tangible tokens. The uses of these ethnological specimens are in most cases well known, a statement which cannot be made in reference to the objects constituting the archæological series, for many of the latter leave a wide scope for conjecture as to the manner in which they were employed by their makers. These doubts extend even to certain types hitherto thought to be well recognized. Thus, many of the so-called arrow and spear heads were not what their names imply, but knives used in connection with short wooden handles. Such cutting-tools have been obtained by Major J. W. Powell among the Pai-utes, and Mr. Paul Schumacher found corresponding implements in graves of Southern California.

The introduction closes with reference to the other valuable collections of the National Museum which illustrate the past or present condition of man in Central and South America, in Asia, Europe, and the other parts of the world.

The first division treats of the most numerous class of relics, namely, those of stone, which are fashioned either by the process of chipping, grinding, or polishing. The first category embraces rude pieces, flakes and cores as well as the more carefully wrought objects, such as arrow and spear heads, perforators, scrapers, cutting and sawing tools, dagger-shaped implements, large implements supposed to have been used in digging the ground, and, lastly, wedge or celt-shaped tools or weapons. The ground and polished specimens, more defined in form, comprise wedges or celts, chisels, gouges, adzes, and grooved axes, hammers, drilled ceremonial weapons, cutting-tools, scraper and spade-like implements, pendants and sinkers, discoidal stones and kindred objects, pierced tablets and boat-shaped articles, stones used in grinding and polishing, vessels, mortars, pestles, tubes, pipes, ornaments, and sculptures.

The objects of copper are described under the following heads. They are either weapons and tools, or ornaments, and have been produced, as it would appear, by hammering pieces of native copper into the required shapes.

The third division embraces the specimens of bone and horn, consisting of perforators, harpoon-heads, fish-hooks, cups, whistles, drilled teeth, &c.

Under the fourth head are enumerated the various objects made of shells. They are either utensils and tools, such as drinking-cups, spoons, fish-hooks, celts, &c., or ornaments, comprising various kinds of gorgets, pendants, and beads.

In the fifth division, which treats of ceramic fabrics, the vessels obtained from mounds of the United States as well as the more elaborate specimens of Mexican fictile art, are described and figured.

Under the sixth head the wooden objects of early date are enumerated. Their number is not very considerable, owing to the perishable character of wood.

In the first appendix the aboriginal methods of hafting stone and bone implements are described and illustrated by eighteen drawings. The second appendix shows the system adopted in classifying the Smithsonian collection, illustrative of North American ethnology.

The implements and samples of workmanship which the Institution has collected furnish a knowledge of the condition of the arts among the primitive people who inhabited this continent. There is, however, another class of ethnological information which cannot be derived from such objects. We allude to the manners and customs of the people, the ceremonies they observe, the myths they transmit, and the religious systems they have adopted. As a general rule it may be assumed that for any usage or ceremony found among them for which no reason can be given there was a corresponding usage in ancient times which had a direct relation to the condition of the people at that time. Hence in order to reconstruct the past history of the different races of men it is of great importance to discover the survivals of the past in present usages. The especial attention therefore of those who have an opportunity of studying those tribes of Indians which have come least under the influence of civilized man has been directed to obtaining accurate information as to the points we have above enumerated.

Indian vocabularies.—For a number of years the Institution has been collecting, as a part of its work in the line of ethnology, Indian vocabularies, and of these the number amounts to 670. They were placed in the charge of J. H. Trumbull, LLD., of Hartford, Conn., for critical examination and arrangement for the press. It was the intention of the Institution to publish these vocabularies as a part of the volumes of the Smithsonian Contributions to Knowledge, and also in a separate form for more general distribution to philologists actually engaged in the comparative study of languages of savage tribes. An offer, however, was made by Maj. J. W. Powell, who had also collected a series of Indian vocabularies, to adopt those of the Institution, and to publish the whole in connection with his researches under Government in regard to the ethnology of the Indian tribes inhabiting the country watered by the tributaries of the Great Colorado of the West. In accordance with the general policy of the Institution in not expending its funds on anything which can be as well done by other means, the proposition of Major Powell was accepted, the only conditions exacted on which the transfer was made being that full credit should be given in the publication to the name of Smithson for collecting and arranging the articles, and also that extra copies be furnished the Institution for liberal distribution.

In connection with these vocabularies the Institution has also transferred to Major Powell, for publication, a grammar of the Ponka language, by Rev. J. Owen Dorsey, of Maryland, who resided for several years as a missionary among the Ponka Indians.

The Institution has also transferred to Dr. F. V. Hayden for publication, in connection with his explorations, the following articles, giving an account of the result of ethnological explorations undertaken under the auspices of the Institution:

"Researches in the Kjökkenmöddings and graves of a former population of the coast of Oregon, the Santa Barbara Islands, and the adjacent mainland." By Paul Schumacher.*

"The Twana Indians of the Kokomish reservation in Washington Territory." By Rev. M. Eells.*

These will also be published with due acknowledgment to the Institution, and extra copies furnished for distribution to its ethnological correspondents.

New edition of ethnological instructions.—In March, 1861, the Smithsonian Institution published a paper entitled "Instructions for Research relative to the Ethnology and Philology of America," prepared by Dr. George Gibbs, an octavo pamphlet of 51 pages divided into two parts, the first relating to ethnology, the second to philology. Under the first head Dr. Gibbs treated of the facts that should be observed and the

* Published in Bulletin of the United States Geological and Geographical Survey of the Territories. Vol. III, No. 1. April, 1877.

material collected, relating to crania, specimens of art, &c., names of tribes, geographical position, number, physical constitution, picture-writing, dress, food, dwellings, arts, trade, religion, government, social life, war, medicines, literature, calendar, and astronomy, history, and antiquities. Under the head of philology he gave a brief account of some of the peculiarities of the Indian languages, with general directions for the best methods of collecting certain words, a simple and practical alphabet, and a comparative vocabulary in English, Spanish, French, and Latin. This vocabulary contains 211 words. The whole was followed by an Appendix A, "Physical Character of the Indian Races," with a tabulated statement on particulars of inquiry, and also an Appendix B, relative to "Numeral Systems."

This paper has been distributed widely among the missionaries, Indian agents, travelers, and local collectors in ethnology, and has served a valuable purpose, resulting in the collection by various persons of the large number of vocabularies previously mentioned, and which comprise nearly all, the languages and dialects of the Indian tribes of the United States, and many in British America and Mexico. It served also to direct inquiry in the several branches of ethnography, resulting in the collection of many valuable notes and minor papers on this subject and many articles illustrating the industries, arts, means of subsistence, &c., among the Indian tribes. It has stimulated investigation throughout the country, giving direction to inquiry, while the results have abundantly proved the value of the instructions and the wisdom of their publication.

The demand for this work has been such that it is deemed important to publish a new edition of it, more comprehensive in plan and more elaborate in detail.

First. It is found necessary to enlarge the alphabet so as to include a wider range of sounds which have been discovered in the North American languages.

Second. It is necessary to enlarge the vocabulary so as to modify it somewhat as experience has dictated, and that new words may be collected.

Third. It is desirable that many simple sentences should be given, so chosen as to bring out the more important characteristics of grammatic structure.

This work, which will form a manual of ethnography, has been undertaken in behalf of the Institution by Prof. J. W. Powell, aided by several eminent ethnologists and philologists, and is well under way.

In this connection I may mention that John Howard Payne, author of "Home, Sweet Home," in 1848 presented to the Institution for publication a large amount of manuscript giving an account of the manners, customs, myths, and religion of the Cherokee Nation previous to its removal from Georgia. He was shortly afterward re-appointed American consul at Tripoli, on the occasion of which he withdrew the manuscript for revision and preparation for the press. He took it with him to his distant post of duty, with the intention of returning it to the Institution, but his sudden death prevented the realization of this intention. We have made inquiry in regard to this manuscript, but have been unable to obtain any information as to what has become of it.

An account of the large additions to the department of ethnology during the last year will be found in the report on the Museum.

MISCELLANEOUS.

The Institution, as in former years, has been in harmonious co-operation with the Department of Agriculture, the Army Medical Museum, and the Corcoran Art Gallery. With the first it has deposited plants and other articles relating to agriculture; to the second it has transferred a large number of articles pertaining to comparative anatomy and materia medica, and has received in return ethnological specimens; in the third, the Corcoran Art Gallery, it has deposited a number of engravings.

Chemical Laboratory.—During a part of the past year the laboratory of the Institution has been in charge of Dr. Oscar Loew, the chemist and mineralogist of the Wheeler Survey, during which time, besides analyzing various mineral waters and other substances collected by that expedition, he has made a series of analyses of minerals for the Institution.

Photography.—In the photographic laboratory, under the direction of Mr. T. W. Smillie, a large number of photographs have been made of ethnological and natural-history specimens. The Institution has continued during the past year the collection of photographic likenesses of cultivators of science in all parts of the world, the whole number received up to this time being over twelve hundred.

Light-house duty.—I have been a member of the Light-House Board since its organization, and during this time have discharged the duty of chairman of the committee on experiments. To the discharge of the duties connected with this service I usually devote one day in the week, and the greater portion of my summer vacation to light-house investigations. A considerable portion, however, of the vacation last year was expended in acting as one of the board of centennial judges. On this account the researches on sound as applied to fog-signals have been deferred until another season.

Fish Commission.—The investigation in regard to food-fishes and the methods of their propagation, for which an appropriation for several years has been annually made by Congress, has been continued under the direction of Professor Baird. This work was commenced in 1872, and has been prosecuted with satisfactory results to the present time.

NATIONAL MUSEUM.

The National Museum was established by the Government in 1842, at which time it consisted principally of specimens collected by the Wilkes exploring expedition. It was transferred from the Patent Office to the care of the Smithsonian Institution in 1858, where it has been enlarged by all the collections made by exploring and surveying parties of the several bureaus of the War, Navy, Treasury, and Interior Departments, and those of the Smithsonian Institution. At first $4,000 only was annually allowed by Congress for the care and exhibition of the specimens. In 1871 the appropriation for this purpose was increased to $10,000, in 1872 to $15,000, and for the last two years to $20,000. Nothing, however, has been allowed for the rent of the building, which was erected exclusively out of the income from the bequest of Smithson.

The following report from Professor Spencer F. Baird, assistant secretary, gives an account of the additions to the museum and the various operations connected with it during the year 1876:

REPORT OF PROF. SPENCER F. BAIRD ON THE ADDITIONS, &C., TO THE MUSEUM IN 1876.

Increase of the Museum.—At no period in the history of the National Museum, from the time when it was organized to the present, has the increase been so great as during the year 1876. A sudden and abrupt augmentation began in 1875, reaching its culmination in 1876. In the absence of funds for the purchase of collections, the ordinary means of increase have been derived, first, from the contributions of Smithsonian correspondents, either spontaneous, or invited with a view of securing material for some particular research; second, from the specimens collected by the various Government surveys and exploring expeditions and transferred to the Smithsonian building in accordance with the law of Congress; and, third, by the exchange of specimens with private individuals or public establishments at home and abroad.

During the two years just past the most important means of increase has been the United States International or Centennial Exhibition of 1876, which has just passed into history as the most extensive and successful of world's exhibitions of natural products and general industries.

In addition, however, to the sources of increase to the Museum during the years 1875 and 1876, mentioned above, still another presented itself of perhaps even greater productiveness, viz, acquisitions from foreign exhibits. With scarcely an exception, the best and most important of these were presented to the United States at the close of the exhibition, embracing, as they did, many complete series of objects, illustrating the geology, metallurgy, the ethnology, and the general resources of all nations. Of about forty governments and colonies, the choicest of the exhibits of thirty-four were presented to the Smithsonian Institution for the National Museum, the remainder either having nothing to give or being restricted in the disposal of their articles.

It was, however, not from foreign commissions alone that collections were received by the Institution. Several entire State exhibits, and many belonging to private parties were also added to the general increase. Nevada, Montana, and Utah presented the whole of their mineral exhibits, while partial collections were received from several other States and Territories.

Of the general collections received during the year, the most noteworthy are the zoölogical specimens brought together by Lieut. George M. Wheeler, during his recent survey, and turned over by him to the museum in accordance with the law of Congress.

Engineer William A. Mintzer, of the United States Navy, also contributed a number of packages, containing collections of natural history and ethnology from Arctic America, collected by him while engaged in mining isinglass on Admiralty Island, north of Hudson's Straits.

The general ethnological collections obtained during the year (principally as the result of expenditure from the centennial fund of the Indian Bureau) are of very great extent. Among the most important may be mentioned those of Mr. James G. Swan, from Vancouver Island, Alaska, and Washington Territory, illustrating the habits of the highly ingenious Northwestern Indians, the more conspicuous of these being the front of an Indian house, a number of carved wooden columns for ornamental purposes, some of them 30 feet long and 8 wide, carved from a single log and properly ornamented, and a dug-out canoe, 60 feet feet long and eight wide.

Mr. Paul Schumacher, in continuing his archæological labors on the south coast of California, made many important acquisitions, adding materially to the variety he had previously gathered. Some additional objects of interest were also received from Rev. Stephen Bowers, of Santa Barbara. Dr. W. W. Hays, of San Luis Obispo, formerly connected with the Smithsonian Institution, also presented a large number of objects, while additional collections were also received from Mr. Stephen Powers, principally of illustrations of the life and customs of the Indians of Nevada and California.

The parties sent out by Major Powell, at the request of the Indian Bureau, to make collections illustrative of the Indians of New Mexico, especially of the Moquis, obtained an extensive collection, including pottery both ancient and recent, stone implements, dresses, &c.

One of the most interesting and important additions to the ethnological collection consisted of carvings of bone and stone implements, contributed by Mr. Lucien M. Turner, United States signal observer at Saint Michael's, on Norton's Sound, south of Behring's Straits. This series, in the number of pieces and variety of shape, the character of the ornaments, &c., is one of the most striking of its kind ever contributed to the museum.

Additional collections of objects were also received from Capt. A. W. Corliss, United States Army, stationed at Tucson.

Not less interesting and important were the archæological collections received from Nicaragua. Dr. Earl Flint, of Granada, furnished many additional specimens to his previous transmissions.

To Dr. J. F. Bransford, United States Navy, is due the most important acquisition ever made from Central America, in the form of a very large number of objects exhumed from Indian graves on the island of Ómotepec, in Lake Nicaragua. These were especially interesting as being found between successive sheets of volcanic eruptions, thus giving a comparative chronology to the objects.

A series of objects illustrative of the *Ainos*, or hairy men of Jesso, furnished by Mr. B. S. Lyman, are of signal interest.

The most important contributions among the mammalia consisted of collections of fur-seals and sea-lions from the Alaska Commercial Company, and a series of eight skins of sea-lions of the California coast (*Zalophus gillespii*) and presented by Capt. J. G. Baker, of the United States revenue marine.

No very large collections of birds were received during the year, with the exception of those from Lieutenant Wheeler's party, although the specimens furnished by Engineer Mintzer from Greenland, by Dr. Hering from Surinam and elsewhere, are noteworthy.

Numerous reptiles in small lots were brought in from various sources. Of fishes, the acquisitions were numerous, consisting mainly of transmissions by agents of the United States Fish Commission. As heretofore, Mr. Vinal N. Edwards, of Wood's Hole, made many important contributions, among which were some fifteen species additional to the known fauna of that locality, which for many years has been the chief station of the Fish Commission.

Mr. Thomas J. Moore, curator of the free public library of the city of Liverpool, transmitted a number of species of English fishes packed in ice for the purpose of having casts made and added to the collections of the Institution. These were consigned first to Mr. E. G. Blackford, of Fulton market, who repacked them in ice and shipped them to Washington. For this, as well as for a continuation of the services of this gentleman in the prompt transmission of rare fishes, the Institution is under great obligations. A special service rendered by him was the transmission, day by day, to the Fish Commission exhibit at the Centennial of all the varieties of fresh fish as they made their appearance in the New York market. Their preservation in large refrigerators, erected at his suggestion by Messrs. Allegretti and Banta, constituted a great source of attraction to the Centennial visitor.

The exhibit made of the fisheries of the United States derived a great deal of its value from the co-operation and contribution of various parties who fully appreciated the importance of making a satisfactory competitive display in view of the anticipated rivalry of foreign governments. Among these, acknowledgment is especially due to Messrs. Bradford & Anthony, of Boston, for undertaking to bring together the fullest series of objects used by the American angler; to Messrs. A. R. Crittenden & Co., of Middletown, Conn., who in like manner prepared the collection of boat-fittings, fisherman's equipments, clothing, &c.; to the American Net and Twine Company, of Boston and New York, which supplied samples of nets of all kinds, models of pounds and fishing-boats, and furnished also miles of netting to serve as ornamental drapery to the building. Mr. J. H. Nichols, of Syracuse, and Mr. Thaddeus Norris, of Philadelphia, also supplied from their private collections a number of angler's equipments.

Here, as in the case of other objects, space does not permit more extended mention; but the detailed enumeration will be found in the list of donations.

The additions to the collections of minerals were enormously large, the principal and most important being a series of ores of the precious metals collected in California, Oregon, Nevada, Utah, Idaho, and elsewhere, by Mr. Thomas Donaldson, and representing a money value far greater than its actual cost, in view of the donation of the specimens by the owners and the agents of various mines.

The collections made by Professor Blake on Lake Superior, by Mr. G. C. Brodhead in Missouri and elsewhere, by Mr. Maury in West Virginia, and by other parties, were also noteworthy. By far the most valuable direct donation, however, was that of the collection of ores and minerals of Nevada collected by the State Centennial board and exhibited with the Smithsonian display. These, with all the cases in which the specimens were exhibited, were presented to the National Museum by the authority of the legislature of Nevada, the same disposition having been made of the very valuable collections of Montana and Utah. Gen. J. H. Wilder, of Chattanooga, presented a large number of specimens from Tennessee. Other series of more or less note will be found detailed in the list of donations.

The present of three large boxes filled with choice minerals of Japan by the government of that country is also a noteworthy addition.

It will be seen from the preceding enumeration that all parts of North America are represented in the accessions of 1875 and 1876, and so uniformly indeed that no one region can be indicated as more worthy of notice than another.

From Central and South America have been received collections in ethnology and zoölogy; from the South Pacific a general collection in natural history; from Japan collections in ethnology and mineralogy. Apart from the Centennial donations comparatively little has been sent in from Europe, a few specimens of birds and ethnological objects representing the series. With the acquisitions made at Philadelphia, however, no part of the world is really unrepresented, as shown by the enumeration of foreign commissions which presented either the whole or a considerable portion of the objects they exhibited from the animal, vegetable, and mineral kingdoms, or as illustrating their ethnology or industries.

It is quite impossible to give, in the limited pages allotted to the present report, anything like a complete statement of the objects thus added to the treasures of the National Museum from the five principal sources thus mentioned. In the Appendix, however, will be found a general statement of the more important objects presented by foreign commissions, arranged alphabetically by countries, the remaining additions being given under an alphabetical list of donors. The catalogue of the display made by the Smithsonian Institution and Fish Commission at the Centennial, for the publication of which it is hoped Congress will shortly make provision, will give a minute enumeration of all objects obtained on that occasion.

Work done in the Museum and at Philadelphia.—As might have been expected, the numerous additions to the collections, resulting from the various donations above referred to, required a corresponding increase of the personnel of the Museum, and a very large force was temporarily employed in receiving and unpacking collections, in preparing them properly for exhibition, in mounting them for suitable display, in cataloguing, entering, and labeling them, in packing for shipment to Philadelphia, in unpacking and arranging there, in caring for them during the exhibition, in repacking and shipping to Washington, and in disposing of them properly at the end of their journey. The funds for this additional service were derived from the special appropriation made by Congress for the purpose. To facilitate the work, several divisions were organized; that of ethnology, under the charge of Dr. Charles Rau, assisted by Dr. Edward Foreman and Mr. Frank H. Cushing; the mineral department, under Prof. William P. Blake, assisted by Mr. Thomas Donaldson; the animal and fisheries divisions were in charge of Mr. G. Brown Goode, assisted by Mr. T. H. Bean and Mr. H. C. Chester.

A series of plaster casts of the fishes, reptiles, and cetaceans of North America was prepared and painted to represent the colors of the living animal. The preparation of the skeletons of whales and other animals of economical interest was done partly at the establishment of Henry A. Ward at Rochester, and partly at the Institution.

The aggregate of the entries of specimens in 1876 amounted to 23,675, showing a very large increase over the entries of 1875 (12,578) and still more over those of 1874, (10,332.)

An accompanying report upon the operations of the Smithsonian Institution, as connected with the centennial display, will give the necessary details in regard to the operations at Philadelphia during the summer, although it may be stated here, in brief, that while the mounting of the specimens, or arranging them in a suitable form for exhibition, was carried on during the whole of the period, the actual packing up and boxing of the specimens began in March, and their shipment in April. Twenty-one car-loads of specimens were forwarded from the Smithsonian Institution, and these were unpacked and put in place with such rapidity, that by the 10th of May, at the opening of the exhibition, comparatively little remained to be done, the whole labor being completed within the subsequent few weeks.

On the 10th of November the work of packing the specimens for their return to Washington was commenced, but was soon arrested by an order of the President directing everything to remain as it was, pending the action of Congress in regard to the erection of a suitable building for the Government exhibit, as more fully detailed in the accompanying report. The interval, however, was made use of in transferring the donations made to the United States by foreign governments and American States and individuals from their previous place of exhibition to the Government building. As soon as the embargo as to packing was removed, these collections, with others constituting the summer's exhibit, were boxed and held in readiness for the anticipated order of the President for their transfer to Washington.

In addition to the twenty-one car-loads of objects moved to Philadelphia from Washington, a large portion of the exhibit of the Smithsonian Institution, arriving from other directions was put in place. Almost the whole of the mineral display was in this category, only one load having gone from Washington.

The collections transferred to Washington after the close of the Exhibition were more than thrice the bulk of those that were taken thence to Philadelphia in the spring, the entire shipment returned occupied forty-two cars, representing approximately an aggregate of 812,000 pounds.

This may be a proper occasion to acknowledge the very great liberality of the railroad companies in regard to the collections in charge of the Smithsonian Institution, and without which the funds at its command would have been inadequate to meet the expense of transportation. By an agreement between the railroad companies and Captain John F. Rodgers, the officer in charge of transportation to and from Philadelphia of the Government collection, full rates were to be paid one way; but all objects thus transferred were to be brought back free of charge. Thanks, however, to the liberality of the Philadelphia, Wilmington and Baltimore, the Baltimore and Potomac, and the Pennsylvania Railroad Companies, no charge whatever was made on the twenty-one car-loads taken to Philadelphia in the spring; and the same companies agreed, without inquiring into the nature of the contents, to bring back to Washington the same number of cars free of expense—additional car-loads to be paid for at the usual rates. It was under these conditions that the liberality of the Philadelphia, Wilmington and Baltimore Railroad, in furnishing, as far as they could be used, hay-cars of extra size, was of so much importance, as it enabled us to pack in a portion of the cars at least 50 per cent. more than in ordinary freight-cars. The remissions of the freights to Philadelphia from various points are due largely to the efforts of Mr. John S. Wilson, of the Philadelphia, Wilmington and Baltimore Railroad Company, acting under the authority of Mr. Isaac Hinckley, president of the road, and to those of Mr. Kingston, of the Pennsylvania Railroad.

Scientific investigation of collections.—In view of the constant labor required in receiving the collections and putting them in proper form for the Philadelphia exhibition, it was impossible to devote much effort to the critical investigation of the collections and their use as material for scientific purposes, although a number of the specimens were placed in the hands of correspondents and collaborators for careful examination, among which are the following:

Mr. Robt. Ridgway, in charge of the department of mounted animals, has continued his investigation of the birds in the National Museum, and has arranged and labeled the entire American collection, involving the handling of over 30,000 specimens.

Mr. George N. Lawrence has examined certain obscure species of the ornithological collection, new to science.

The *Rodentia* have been investigated by Dr. Elliott Coues, who has prepared therefrom material for an elaborate monograph to be published in Professor Hayden's series of reports. Several new species have rewarded his labors. A preliminary report has lately been made by him of the shrews, which will form the subject of a second work by the same author.

Prof. Edward Cope has received various collections of reptiles from the Institution, and has submitted them to careful examination.

Dr. Thomas H. Streets, surgeon United States Navy, has been engaged during the year in investigating the collection of vertebrates and other animals obtained by him during a recent United States survey of the South Pacific and the Gulf of California made by the United States ships Portsmouth and Narragansett. He has discovered several new species, an account of which, with his other notes, will be published in the Bulletins of the National Museum.

Professor Gill has continued his labors upon the general and systematic arrangement of the mammals and fishes.

The ethnological collection has also been the subject of considerable inquiry. Professor O. T. Mason, of Washington, has undertaken a memoir upon a remarkable collection of stone implements from Porto Rico, presented to the National Museum by the late Mr. George Latimer. This will be fully illustrated and form part of the report of the Institution for 1876.

Dr. Rau has prepared a work on the American stone age, to serve as a guide to the archæological exhibit of the United States, and which has been published by the Institution.

Dr. James Lewis has completed, during the year, his investigation of the fresh-water and land shells of the United States belonging to the Museum, and has carefully identified and labeled the species. A series was reserved by him for the Museum and the duplicates made up into sets for distribution.

Dr. Edward Foreman has also thoroughly identified the vegetable substances used by the American Indians as food, medicine, narcotics, paints, &c., and has made up numerous sets for distribution to ethnological establishments.

Distribution of duplicate specimens.—The same reasons which prevented the usual effort in regard to researches among the collections has more or less interfered with the distribution of duplicates during the year; but as the amount of material available for the purpose has been greatly increased as a result of the Centennial collections, it is hoped that the coming year will permit an unusual amount of effort in this direction.

A considerable number, however, of zoological, mineralogical and ethnological specimens, either singly or in sets, have been sent off as direct donations or exchanges. Their aggregate, including that for 1875, will be found in the usual table of the appendix.

Present condition of the Museum.—The great enlargement of the Museum has commensurately expanded its means for scientific and practical instruction. In many departments it may claim very great eminence, entitling it, on the whole, to rank with the largest European collections, while in some respects, especially as regards the ethnology, mineralogy, and zoology of North America, it may fairly be said to occupy the very first place among museums of the world. The immense mass of duplicates now in its charge also constitutes so much material for increasing the present number of species, and when proper facilities are afforded for unpacking and arranging its reserve series, great additions can be made by a suitable system of exchanges. At present, however, everything looking toward such final arrangements is contingent upon provision by Congress in the way of increased accommodations, since the present available space is entirely inadequate to the purpose.

The Museum portion of the Smithsonian edifice consists of two rooms of about 10,000 feet area each, with a connecting range and gallery of about 5,000 feet. The specimens in cases are at present very much crowded, while very many others are in boxes, occupying the passages and intermediate spaces. The basement of the Institution, nearly 400 feet long, is a series of store-rooms, for the reception of portions of the collection not yet exhibited in the upper halls, and thus without benefit to the general public. Among these objects are very many skeletons, beautifully prepared by Professor Ward, some 40,000 jars of alcoholic specimens, together with several hundred large copper tanks, likewise filled; over 50,000 skins of birds, of which at least 15,000 should be mounted and placed in the general collection; several thousand skins of mammals; large numbers of fossil vertebrates, minerals, ethnological objects, &c.; these, for the most part, not duplicates, but simply specimens for which there is no room elsewhere.

An estimate of 25,000 square feet, or a space equal to that of the upper halls, is by no means extravagant for the proper display of the specimens thus excluded. Anticipating the necessity of increased accommodations for the Centennial collections and accessions, the Smithsonian Institution, in 1875, made application to Congress for the use of the Armory building in the square between 6th and 7th Streets, an edifice 100 feet by 50, having four floors. This it was supposed would be adequate, at the close of the Centennial, for the reception and exhibition of at least the fishery exhibit and that of economical mineralogy. So great, however, was the surplus of Centennial material to be provided for that the building is now filled with boxed specimens, occupying for the most part the entire space from floor to ceiling of each room. The building is not fire-proof, and although the specimens in it represent some of the most valuable and important of the series, there is nothing to prevent their destruction by fire, or injury from damp, vermin, or other causes, a result which would constitute an irreparable loss.

As the four floors of the Armory referred to present 20,000 feet of area, an estimate of 50,000 feet for the proper display of the specimens now stored in them cannot be considered extravagant, thus making the entire additional space required, 75,000 square feet. Only one-fourth of the specimens in charge of the Institution are at present on exhibition, the remainder being entirely withdrawn from public inspection, so that the necessity for prompt effort to secure the proper accommodations will be readily nuderstood.

There can be no question as to the scientific and industrial value of the specimens thus added to the national collections, as they consist, not of the ordinary objects of natural history alone, but of those which show the natural and industrial resources of the country, and constitute, in very great part, that material which to the American manufacturer and producer is of the utmost value as constituting the objects of their study. Indeed, their acquisition by the United States tends to render the benefits of the international exhibition permanent to a great degree; it is, therefore, of importance that, while the lessons of the exhibition are still fresh in mind these objects should be exhibited and attention invited to them. Numerous applications have already been made for permission to make a study of the objects, which, on account of the impossibility of furnishing space for unpacking them, for the most part have been refused. The great number of duplicates, too, should be distributed as speedily as possible to the various points throughout the country requiring them. Of course, this cannot be done under present circumstances.

Nature of increased accommodations required.—In view of the fact that the collections for which provision is needed represent a bulk of at least three times the present capacity of the Smithsonian building, it is evident that to accommodate these, and to make reasonable provision for probable increase in the future, a building of great magnitude will be required. If, however, this be constructed according to the usual plan of Government buildings in Washington, the expense would be so very great as to render it doubtful whether the necessary appropriation can be obtained, and in any event the period of time required for completing the edifice would extend over so many years that the greater part of the collections now boxed might be destroyed by rust, decay, the attacks of insects, &c., while the country would lose the stimulus of the exhibition and the benefits of its study.

Any new edifice should be in connection with the present Smithsonian building, and, in a measure, form its extension, so that the entire National Museum might be together, and a single supervision extended over the whole.

After a careful consideration of the problems relating to the subject of a building, a plan has been settled upon to be presented to Congress for its consideration, which, it is believed, embraces, in a very marked degree, the requirements of economy, space, convenience, comfort, and freedom from danger of fire. The idea of this was suggested by General Meigs as the result of his special inquiries into public buildings and museums abroad, and the details have been worked out by Mr. Cluss. This involves an edifice with a floor area 300 feet square, and so arranged as to be capable of being excellently lighted. A concrete floor is proposed, for the purpose of keeping out moisture and preventing the lodgement of vermin, with brick walls and an iron, slate, or metal roof. It is believed that such a building can be completed and provided with the necessary heating-apparatus at a cost not to exceed $250,000, or about $2.84 per square foot. By its simplicity and uniformity of structure, and the absence of cut-stone or carving, it is thought that the whole can be completed and ready for occupation within ten months' time from its commencement.—S. F. BAIRD.

GOVERNMENT EXPLORATIONS AND SURVEYS.

The following are brief accounts of the principal explorations of the Government in 1876, from which specimens will be derived for increasing the collections of the National Museum. They are furnished by the several directors of the explorations.

1. *Under Lieut. George M. Wheeler, Engineer Department, U. S. Army.*—The geographical surveys west of the one hundredth meridian, under

First Lieut. George M. Wheeler, Corps of Engineers, United States Army, and reporting to Congress through the Engineer Bureau of the War Department, were begun in 1869. In that year the present officer in charge, while making reconnaissances for routes of communication through Southern Nevada, conceived the idea of extending the work to other portions of the Military Department of California. A plan for the prosecution of the same was presented while elaborating the results of that year's work. Lack of funds prevented operations in 1870, but in 1871 parties again took the field in Nevada, California, and Arizona.

At that time the work received its principal support from the appropriation for "Surveys for Military Defenses," under which head it naturally fell. In 1872, however, Congress appropriated special means and a more complete organization was made, the survey being prosecuted principally in Utah, but also in Arizona and Southeastern Nevada. In 1873 the character of the methods employed upon this work advanced in proportion with the prospect of its development into an accurate geodetic survey, extending over large areas. During this season many points accessible to the telegraph were occupied for completing the system, now extending from Eastern California, Nevada, and Northern Arizona to the eastern base of the Rocky Mountains. In 1874, connection between the east and west portions was made more perfect. In 1875 the operations of the survey were conducted in two divisions, designated as the California and Colorado sections, the former acting in portions of the southern sierras and extending from the branches of the coast-ranges south of latitude 37°, eastward toward the Colorado desert, while the latter expanded the finished area of 1873 and 1874 in Colorado and New Mexico.

The distribution of areas surveyed thus far is as follows:

	Square miles.
In Nevada	58,940
In California	40,625
In Arizona	60,120
In Colorado	37,550
In Utah	44,015
In New Mexico	53,236

The maps issued to date cover areas as follows:

	Square miles.
On a scale of 1 inch to 8 miles	192,217
On a scale of 1 inch to 4 miles	13,028
On a scale of 1 inch to 2 miles	1,091

During the season of 1875 one party of the California section continued examinations for determining the practicability of diverting the Colorado River for the purpose of irrigation. The report of Lieutenant Bergland on this subject, and the information already submitted by the officer in charge of the survey, are sufficiently full to place this matter at rest for the present.

Aside from the topographical work of 1875, gratifying results in ethnological research were obtained by a party of the California section under Dr. H. C. Yarrow, detailed for that purpose. Extensive burial-places were discovered, and it is estimated that the remains of no fewer than 5,000 individuals were exhumed. The valuable collection made has been submitted to Professor F. W. Putnam, of the Peabody Museum of Archæology, for examination and study. Dr. Yarrow's report fully describes the explorations of this party.

The geology of portions of Southern California, Arizona, New Mexico, and Colorado was examined and reported upon by Prof. Jules Marcou, Dr. Loew, and Mr. A. R. Conkling. Professor Marcou makes valuable additions to the knowledge of the field visited by him. Dr. Loew describes much of geological interest in his work of the year, besides making a large collection of specimens. He also determines the chemical composition of alkaline and other deposits, and of the waters of thermal and mineral springs of Southern California, and analyzes the ores from several mines. Mr. Conkling made a rapid and interesting examination of the mountain geology from La Veta Pass to the head of the Pecos River. Much valuable mining information of a descriptive character was obtained by the different parties.

The meteorological and hypsometrical methods, as described by Lieutenant Marshall, show a commendable state of efficiency. The economic botany and agriculture of Southern California received careful consideration from Dr. J. T. Rothrock, acting assistant surgeon United States Army, and his observations cannot fail to interest those in search of information regarding that country. In the field of zoology Mr. H. W. Henshaw displayed his usual energy. During the season 700 ornithological specimens were secured, representing 127 species. The report of this gentleman describes the habits, peculiarities, and localities of these birds.

The operations of the season of 1876 were carried on in portions of Colorado, New Mexico, California, and Nevada. The Colorado party, traversing atlas-sheets 52, 53, 61, and 62, occupied 10 main and 51 secondary triangulation stations, with numerous three-point, sextant latitude, and meander stations, covering an area of 4,800 square miles. The party in New Mexico, operating upon an area of 7,500 square miles, in atlas-sheets 62, 69, 70, 77, 78, and 84, occupied 15 triangulation, 191 three-point, and a large number of subordinate stations. Corresponding results were obtained by each of the four parties acting in Nevada and California. Base-lines were measured at Sutro, Nevada, and Colorado Springs, Colo.

The working force of the season was disposed as follows: (1) the California section, in charge of Lieutenant Wheeler, with its several parties under the command of Lieutenants Tillman, Symons, Birnie, and Macomb; (2) the parties of the Colorado section, under Lieutenants

Bergland and Morrison; (3) the office force in Washington, temporarily in charge of Mr. George M. Lockwood.

The two sections were rapidly organized, and, except in case of the New Mexico party, were placed in areas readily approached, in order to gain full advantage of the season, rendered necessarily short by the lateness of the appropriations. The results accomplished are of more than usual value. The detailed topographical notes from that part of the Sierra Nevada within which lies Lake Tahoe, surrounded by a number of outlying miniature lakes, will admit of publication upon a scale of 1 inch to 1 mile. Minute topographical details, by the plane-table method, admitting of reproduction on a scale of 1 inch to 500 feet, if required, were gathered in the vicinity of Virginia City, Nev., by a party dispatched thither for the purpose of measuring a base-line.

As the result of this season's barometric work, 749 cistern-barometer and 3,804 aneroid stations were occupied. The highest point reached was Pike's Peak, 14,150 feet; the lowest was Sulphur Springs, Nev., 3,575 feet. Fourteen mining-camps were visited.

During the past year the following publications have been made: 1 progress-map; 2 crayon atlas-sheets; 7 topographical atlas-sheets; 6 geological atlas-sheets; map of Lake Bonneville, (restored outline of an ancient fresh-water lake;) preliminary report of 1869, revised edition; annual report of 1876; Volume III (Geology) of general report; Part I (Invertebrates) of Volume IV, (Paleontology;) and Volume V, (Zoölogy.) Progress has also been made upon Volumes I, II, VI, and VII, and it is expected to have the MS. of three of them in the hands of the printer at an early date. The manuscript for Catalogue of Declination of 2,018 stars has gone forward.

The small amount of the appropriation did not admit of the employment of the usual number of geologists, zoölogists, &c., but Mr. A. R. Conkling, as geological assistant, and Mr. H. W. Henshaw, as zoological collector, accompanied the California section. Observations in geology were confined chiefly to the eastern and western summits of the Sierra Nevada Range. Abundant evidence of the former existence of glaciers is found in the mountains on the southwestern side of Lake Tahoe. Glacial scratches were observed on Tallac Peak. Vast surfaces of rock have been polished and grooved by these moving masses of ice, and well-marked terminal moraines are seen on the southern banks of the lake. Some very picturesque lakes occur in front of Tallac Peak, and, according to Prof. Jos. Le Conte, who has studied this region carefully, these lacustrine areas have been scooped out by glacial ice.

Near Lick's Point, Lake Tahoe, a compact phonolite is found. The northern side of the lake is bounded by granitic ridges. In the Eastern Summit there are several ore-deposits. The principal mines are the Montreal, Emerald, Niagara, and Clear Creek Cañon. The Carson Valley contains numerous hot springs, and several basaltic buttes occur on the plain of Carson City. About one mile east of the town a mass of yellow sandstone outcrops, which is fossiliferous, the bivalves of the genus *Unio* being very numerous.

The work of Mr. Henshaw, collector in zoölogy, was mainly confined to the vicinity of Carson City, Nevada, and the region contiguous to Lake Tahoe. In the character of its avian fauna the pine region of the eastern slope of the Sierras was found to nearly resemble that of the western side, and some birds, distinctively Californian in nature, were ascertained to range down to the foot-hills on the borders of the sage-brush plains of Nevada.

The fish of the various streams and lakes of this well-watered region received careful attention, and extensive collections were made. Specimens of such insects as remained at this late season were collected, and, though the results are not large, it is more than probable that they include a number of novelties, especially among the Orthoptera.

The section of country visited will prove of most value for timber, grazing, and mineral purposes, as in most instances the altitude of the high interior mountain-ranges precludes the certainty of crops, even where there is arable ground. In favorable exception to this rule, however, may be noted the land in proximity to Honey Lake, in the northern part of the California area, and on either side of the Rio Grande, below Albuquerque, in New Mexico.

An important feature of the present stage of the survey results from the instructions which require each chief of party or topographer to take notes sufficiently detailed to permit the plotting, upon resource-sheets, of the limits between arable, irrigable, grazing, mining, and timber lands, indicating, also, those absolutely barren. In the office, in addition to the regular geographical atlas-sheets, certain preliminary maps have been arranged, from which will be prepared colored sheets, upon which areas will be so delineated as to readily convey to the eye the general capabilities of the section embraced. These delineations, together with the tabulated results of the season's observations, will give a complete account and almost perfect idea of the natural resources of the country and its availability for agricultural, mining, and grazing purposes, and will graphically separate the arid, barren, and otherwise worthless tracts from the better land. In future operations it is intended to procure complete statistics on these important points, and the material of former years having been digested, the comparison of large areas will then be practicable. In addition to the data disclosing the natural resources, the direction of drainage, with basin perimeters, will be indicated, and the amount of rain-fall determined as nearly as practicable. The sheets and tables will then furnish fair data for deciding upon the feasibility of irrigating by canals, reservoirs, and artesian-wells. These maps will be completed as rapidly as the limited force and relative importance of different portions of the work will allow.

Through an inadvertence on page 56 of the Annual Report of the Institution for 1875, it is stated in relation to geographical surveys west of the one-hundredth meridian, that connection was had with the base-line measured by Captain, now Brig.-Gen. E. O. C. Ord, near Los Angeles, Cal., in 1854. The "base" in question was measured in April and May 1853, by Assistant George Davidson, United States Coast Survey.

2. *The work of the United States Geological and Geographical Survey of the Territories, under the direction of Professor Hayden, during the season of 1876.*—The United States Geological Survey for the season of 1876 was divided by Dr. Hayden into five parties for field-work. The late date at which the appropriation was made available delayed the commencement of the work until late in August, so that only the completion of the atlas of Colorado was attempted and successfully accomplished. The work of 1876 was therefore a continuation westward of that of the three preceding years, finishing the entire mountainous portion of Colorado with a belt of Northern New Mexico, 15 miles in width and a breadth of 25 miles, of Eastern Utah, and also a rectangle of Arizona, 15 by 25 miles. The areas of exploration are located in the interior, remote from settlements and largely on the reservation for the Ute Indians. Each party was assigned a special area for examination, which was so selected as to connect with each other topographically. The common point of departure was Cheyenne, in Wyoming Territory.

The main division or party of primary triangulation was under the charge of A. D. Wilson, and accompanied for part of the season by Dr. F. V. Hayden, director of the survey. The object of this party was to complete the primary triangulation of Colorado. The field was taken at Trinidad, the southern terminus of the Denver and Rio Grande Railroad, and the first station was made on Fisher's Peak, a point near Trindad. Marching thence westward through the Raton Hills, a station was made on Culebra Peak, one of the highest points of the Sangre de Cristo Range. Crossing the range, the next point was Blanca Peak, the highest peak in Colorado, one of the Sierra Blanca group of the Sangre de Cristo Range. Its elevation is 14,464 feet above sea-level. From the Sierra Blanca the party proceeded westward across the San Luis Park and up the Rio Grande to its source, making two stations on the way, one near the Summit district and the other on the Rio Grande Pyramid. From the head of the Rio Grande the Continental divide was crossed, and the next station made on La Plata Peak in the La Plata group of the San Juan Mountains. From this point the party turned northwest, traveling across the broken mesa country west of the Dolores, making three secondary stations to complete the topography omitted in 1875 on account of the hostility of the Indians. After occupying the highest point of the Sierra Abajo, one of the isolated mountain-groups of the plateau region, they went eastward to Lone Cone, where another station was made. Thence they proceeded northward, via the Uncompahgre agency, crossing the Gunnison and Grand Rivers to the plateau region at the head of White River, a branch of the Green.

The final station was made between the White and Yampah Rivers, in the northwestern corner of Colorado. In the two months he was in the field Mr. Wilson traveled 1,400 square miles, finished about 1,000 square miles of topography, and also made eleven geodetic stations, connecting by a system of primary triangles the whole of Southern and Western Colorado with the triangulation of the previous years. Mr. W. H. Holmes accompanied the triangulation-party as geologist. From the rapidity with which they were obliged to travel he was unable to do much detailed work, but he had an excellent opportunity to correlate the formations of the plains east of the mountains with those of the pleateau region on the west. As he had previously surmised, he found the structure of the Sierra Abajo to be identical with that of the other isolated mountain-groups to the south and east of the Abajo in in his district of 1875. A mass of trachyte has been forced up through fissures in the sedimentary rocks, and now rests chiefly upon the sandstones and shales of the Lower Cretaceous. The sedimentary rocks are arched from the intrusion of wedge-like sheets of trachyte, and the broken ends of the beds are frequently bent upward, as if by the upward pressure of the igneous mass. The division left the field about the 12th of October at Rawlins Springs, in Wyoming Territory.

The Grand River division was in charge of Henry Gannett, topographer, with Dr. A. C. Peale as geologist. James Stevenson, executive officer of the survey, also accompanied the party a portion of the season. The party took the field at Cañon City, August 23, and marched westward to the Uncompahgre agency, a few miles east of the lower district assigned to the division. The country assigned to it for exploration consisted of two detached portions, one of about 1,000 square miles, lying south of the Sierra la Sal and east of the Sierra Abajo, extending eastward to the Rio San Miguel and southward as far as the latitude of Lone Cone. The other lay north of the Grand River, extending from the river to the crest of the Roan or Book Cliffs. Its eastern limit was the meridian of 108° and the western 109° 30′, comprising about 3,000 square miles.

Work was commenced in the southern district early in September. The country surveyed is entirely made up of broken plateaus, almost without water, except in the Dolores and San Miguel Rivers, and several smaller streams. It has very little agricultural value, but portions of it would make fair winter-ranges for stock. The region, however, is geologically interesting, on account of several folds which, with the subsequent erosion, have beautifully exposed the several formations. Coal occurs at several places in the Cretaceous rocks, and on the Uncompahgre River, a few miles above the agency, there is semi-anthracite coal. Gold placers have been discovered on the San Miguel River, and in the mountains south of the district prospecting has been vigorously prosecuted. This portion of the San Juan mining region bids fair to become one of the most important and successful districts, as indicated by the developments already made.

The northern area is occupied by the valley of Grand River and the foot-hills of the Roan Plateau, forming the Book Cliffs. The valley of the Grand extends down the north side of the river for upward of a hundred miles, with an average width of 10 miles, and is at present about as valueless a piece of country as there is in any part of the West. There is no good water except in the Grand, which is in low cañon most of its course and consequently difficult of access. The soil is a bluish-gray alkaline clay, derived from the weathering of Cretaceous shales, which, when dry are deep and powdery, and when wet become a mud of almost incalculable depth. There is but little vegetation of any kind. Part of the valley might be irrigated from the river and thus become of value. The geology is comparatively simple, the different formations dipping away from Grand River in regular order from Triassic to Green River Tertiary, the latter forming the summit of the cliffs. Coal occurs along the cliffs, but at no locality visited was it of economical importance. The most interesting discovery was that of asphaltum springs, on the southern side of the crest of the Roan Plateau. The mineral tar flows from fissures in Tertiary sandstones and hardens as it pours down the walls of the cañons on which it occurs. About a dozen of these springs were noted, some of them in connection with sulphur springs.

The party, after finishing the northern area, started for Rawlins, on the Union Pacific Railroad, which they reached October 23, having been in the field two months. In that time they traveled about 1,100 miles, locating 55 topographical stations, and surveying 4,000 square miles in about 35 working days, the rest of the time being occupied in marching to and from and between the districts.

The White River division was directed by George B. Chittenden, as topographer, accompanied by Dr. F. M. Endlich, as geologist. The district assigned to this party began on the east at longitude 107° 30′, joining the work previously done, (1874,) and extended westward to longitude 109° 30′, or about 27 miles over the Colorado line into Utah. Its southern boundary was north latitude 39° 38′ or the approximate line of the Book Cliffs, while the White River formed the northern limit. The area surveyed comprised about 3,800 square miles. In working up the topography of this district the party spent 48 days of absolute field-work, made 41 main topographical stations and 16 auxiliary ones, and traveled within the district about 1,000 miles. The country has hitherto been almost entirely unexplored, and had been described by the nearest settlers as a broken cañon country, extremely dry. It was marked on the maps as a high, undulating plateau, with fresh-water lakes and timber. The party saw no lakes of over 400 yards diameter, and but two or three of these, and timber was rather the exception. The country is nearly all inhabitable, both winter and summer, and considerable portions of it are valuable. About three-quarters of it is within the limits of the Ute Indian reservation.

The general topography is a gentle rise from White River toward the south, and a sudden breaking off, when the divide is reached, into rugged and often impassable cliffs, known on the maps as the Roan or Book Mountains. The gentle plateau slope of the White River slope is cut by almost numberless and often deep cañons, and in many cases the surface of the country has been eroded away, leaving broken and most picturesque, the lower benches generally covered with cedars and piñons, and the upper rich in grass. There are four main streams draining into the White, the most eastern of which is a large running stream. The second has in summer no running water for the greater part of its course, although pools of good water may be found in its bed. The third is for the most of its length a mere trickling stream of alkali water; while the fourth and most western one is dry for 25 miles from its mouth and then forks, one branch containing good water in pools, while the other is a running stream of bitter alkali. The trails generally keep on the summits of the ridges to avoid crossing the numerous cañons. Geologically speaking, the district is one of singular uniformity. Traveling westward, the older formations, reaching back as far as the Triassic, were found. These were followed by Cretaceous, which in turn was covered by Tertiary. About three-quarters of the region surveyed is covered with beds, belonging to the latter period, dipping gently from the summit of the Book Cliffs northward. Owing to the lithological characters of the strata, water was a rare luxury in most parts of the district. In the far western portion and outside the limits of the reservation, one large vein of asphaltum and several small veins were found, with, also, running springs of the same material, all of which, if once reached by railroads, will prove of great commercial value. At present, they are about 50 miles from white settlements and 100 miles from the nearest railroad communication. Work was completed October 14, and the party marched eastward through Middle Park to Boulder City, Colo., having been in the field rather more than two months.

The Yampah River division, in charge of Gustavus Bechler, with Prof. C. A. White as geologist, reached the field late in August. The district assigned to the party for exploration is virtually the northwestern corner of Colorado, embracing also a small belt of country lying in Utah. The Bear or Yampah River forms the natural boundary of this area on the north as the White does on the south; both tributaries to the Green and eventually of the great Colorado of the West. Their course in general is westward through the whole extent of the district. The eastern and western limits of the district are the same as those of the White River district, which lies immediately to the south of the Yampah district. Between the two rivers the country is composed for the greater part of plateaus or table-lands, which, according to their elevation, have the features of high plateaus, terraces, benches, and offsets. This belt of country is about fifty miles in width. It is cut by dry cañons and gorges, with scarcely any grass or timber. From the White River agency, White River takes an almost due west course for about eighteen miles, most of the way through an open valley, with here and there a few narrow gorges. About fifty miles below the agency the valley opens into a broad barren expanse, with scanty vegetation. Soon after the river enters a cañon, the walls of which increase until it flows into the Green.

The Yampah deviates but seldom from a westerly course. Like the White, it flows through a plateau country, which rises gently from the river back for a distance of about eight miles. South of the river are the Williams River Mountains. The Yampah traverses the country more or less in a cañon, occasionally emerging into open grassy valleys. Where the Snake, one of its tributaries, comes in there is a park about 8 miles in length from east to west, surrounded on all sides by eroded terraces and plateau spurs that rise by steps to the divide on either side. Leaving this park, the river enters a huge fissure, and continues in cañon until it joins the Green, in longitude 109° 40′ and latitude 32° N. After the Yampah joins it, the Green also continues in cañon for the greater part of its length. All these rivers have numerous branches from both sides, forming deep cañons the greater part of their length. As a whole, the district is very arid and barren, and almost destitute of trees. The total area surveyed by Mr. Bechler is about 3,000 square miles. The rocks of the district, studied by Dr. White, the eminent palæontologist, embrace all the sedimentary formations yet recognized by the investigators who have studied the region that lies between the Park Range and the Great Salt Lake, viz, from the Uinta quartzite (which underlies the Carboniferous) to the Brown's Park group, or latest Tertiary, inclusive. Much information was also obtained concerning the distribution of the local drift of the region, the extent and geological age of outflows of trap, &c. The brackish-water beds at the base of the Tertiary series, containing the characteristic fossils, were discovered in the valley of the Yampah. They are thus shown to be exactly equivalent with those from the valley of Bether Creek, in Wyoming Territory. The work of the past season shows very clearly the harmonious relations of the various groups of strata over vast areas; that, although there may be a thickening or a thinning out of beds at different points, they can all be correlated from the Missouri River to the Sierra Nevada Basin. Dr. White remarks that the line between the Cretaceous and Tertiary epochs must be drawn somewhere, but that it will be strictly arbitrary, as there is no well-marked physical break to the summit of the Bridger group.

The Zoölogical division was in charge of Dr. Elliott Coues, U. S. A. The party left Cheyenne on the 15th of August, and traveled westward to Laramie Plains and thence southward into and through North Park. From North Park they proceeded to Middle (Egan) Park, and finally returned to Cheyenne via Berthoud's Pass and the plains east of the mountains. Collections in various departments of zoölogy were made along the whole route traversed, but particularly on and near the Rabbit Ear range of mountains; and careful observations were taken of the various zoölogical phenomena which presented themselves. The collections have been deposited in the National Museum, with the exception of the osteological material, which has been donated to the Army Medical Museum. The material secured will become the basis of Dr. Coues' reports upon the zoölogy of the region explored. In the general field-work the zoölogist in charge was ably assisted by Mr. L. M. Cuthbert, of Washington, and Mr. W. W. Karr, of Memphis.

The Photographic division of the survey did not take the field during 1876, partly on account of the lateness of the season, but also in part because of the accumulation of office-work. Mr. Jackson, the photographer, remained in Washington during the summer engaged in arranging the collection of Indian photographs and preparing material for the publication of a historical and biographical catalogue of photographs of seventy-five tribes of the North American Indians.

The survey, in addition to its field-work, prepared an exhibit for the International Centennial Exhibition. The exhibit was divided into models, maps, photographs, publications, sketches, and pictures in water-colors, and chromos, and specimens. There were two classes of models, one representing geological structure and the other the ancient ruins of Southwestern Colorado and portions of adjacent territories. One of the latter class represents a two-story cliff-house of the Rio Mancos of Colorado. It is built in the crevice of the rock, 800 feet above the valley, in an almost inaccessible situation. Another model represents the ruins of a double-walled tower, a form of building that seems to have been common among the ancient inhabitants of the region. There were also two models of a cave-dwelling of the Rio de Chelly of Northeastern Arizona, one representing the ruins and the other their ideal restoration. The geological and topographical models were as follows: Two of the Elk Mountains, one of them being divided into sections, showing the internal structure of the range, and the other showing only the topography and geology, the latter represented by colors. The maps on exhibition were topographical, geological, and hypsometric. The photographs and positives on glass represented the scenery and ruins of the West and the hot springs of the Yellowstone National Park. Full sets of the reports, with sketches in color of scenery and in crayon of Indians, and also specimens from the Yellowstone hot springs, added to the exhibit.

During 1876 the following publications were issued by the survey:

Bulletins, volume ii, (Nos. 1, 2, 3, and 4,) comprising over 300 pages, with 110 illustrations.

Eighth Annual Report, (Colorado and adjacent territory,) 515 pages and 88 illustrations.

Monograph of the Geometrid Moths, by A. S. Packard, jr., 607 pages and 13 plates.

Invertebrate Paleontology, by F. B. Meek, 629 pages, with 85 woodcuts and 45 plates.

Catalogue of Publications, second edition.

3. *Exploration of the Rocky Mountain Region by Prof. J. W. Powell.*—As soon as the appropriation for the fiscal year of 1876–'77 could be used, the surveying corps left Washington and proceeded to the rendevouz camp at Gunnison, Utah, where the field parties were organized under the general superintendence of Prof. A. H. Thompson, geographer of the expedition. While *en route* they were joined by Capt. Clarence E. Dutton, of the Ordnance Department, U. S. A., who had been assigned for duty on this survey by the Secretary of War, and directed to make an examination of the immense fields of igneous rocks in Southeastern Utah.

The field organization as finally completed differed somewhat from that of previous years—the geographic and geological work being assigned to separate parties, each practically independent in all movements, though working under the same general plan and within the same territorial limits. It is believed that better results can be and have been secured by this separation of distinct branches of the survey than by the old method of attaching a geologist to a geographic party or a geographer to a geological party.

Five parties were organized—one under Prof. A. H. Thompson, to continue the triangulation; one topographic party under Mr. Walter H. Graves, another under Mr. John H. Renshaw; one geological party under Mr. G. K. Gilbert, another under Capt C. E. Dutton.

The party under Professor Thompson continued the expansion of the primary triangulation resting on the base-lines measured in preceding years at Kanab and Gunnison, Utah. The area embraced in this season's work amounts to about 10,000 square miles, the instrument used being a ten-inch theodolite of peculiar construction, designed especially for this work by Professor Thompson.

Topographic party No. 1, in charge of Mr. Graves, extended the secondary triangulation over an area of 6,000 square miles, lying between the Wasatch Mountains on the west, and the Green and Colorado Rivers on the east. Mr. Graves also made a complete plane-table sketch of the country surveyed, which, taken in connection with his angles for locations and perspective profile sketches, will enable him to construct a map of his district on a scale of 4 miles to the inch. The principal topographic characteristics of this region are long lines of unscalable cliffs, the escarped edges of terraced plateaus, of which the country is composed, and deep, narrow cañons with vertical walls, both presenting well-nigh impassable barriers to travel.

The only considerable bodies of irrigable lands found are along the valleys of the Green and San Rafael Rivers. The only timber-lands are on the Sevier plateaus at an elevation of from 8,000 to 11,500 feet.

The work of topographic party No. 2, under Mr. Renshaw, was confined to Southwestern Utah and Southeastern Nevada, one of the most rugged and barren sections in the Great Basin. The methods of survey were the same as adopted by party No. 1, except that perspective profile sketches were made by the aid of the orograph, a newly designed instrument that promises to be of great use in topographic surveying. The work of Mr. Renshaw and his able assistant, Mr. O. D. Wheeler, was extended over about 4,000 square miles. In all this area no considerable bodies of irrigable lands are found; probably not one-half of one per cent. possessing any value except for pasturage.

A topographic survey of the Henry Mountains was made in 1875, and a map constructed on a scale of 4 miles to the inch, but this being thought too small a scale to admit of correct representation of the details of the geology, Mr. Gilbert, in addition to his geological work, made a more detailed survey of the topography, carrying a complete system of secondary triangulation and a connected plane-table sketch over more than 1,000 square miles. The data collected are sufficient to make a topographic map of the Henry Mountains on the scale of 2 miles to the inch, or 1-63000.

The Rocky Mountain Region of the United States, (not including Alaska,) or that portion west of the meridian of 99° 30′, was by a former Secretary of the Interior divided into districts for surveying and mapping purposes, and these districts numbered; the area of each district is 2½ degrees in longitude, and 1¼ degrees in latitude. The region of country surveyed by the parties under the direction of Professor Powell is embraced in districts numbered 75, 85, 86, 95, 96, 104, and 105, the first five lying directly west of the region in which Dr. Hayden is engaged, while districts 104 and 105 lie immediately south of the other districts in which he himself has been at work. During the earlier part of his work, before these districts were established by the Department, Professor Powell's work extended in an oblique direction from northeast to southwest along the general course of the Green and Colorado Rivers through the districts above designated, but the work was in such condition that no one district was complete. During the present season his parties have been engaged in extending the survey over the unsurveyed fractional districts, so that final and complete maps of each may be constructed.

The methods of survey during the present season are essentially the same as those employed during the last, being modified to a slight extent as experience has suggested; the chief improvements are in the method of triangulation. In addition to the determination of geodetic positions and general geographic features, the system of classifying the lands inaugurated in former years has been continued during the present, the object of this classification being to determine the extent and position of the irrigable lands, timber lands, grass lands, mineral lands, and waste lands; the latter being composed of rugged mountains and desert plains. The practical importance of this classification, if carefully made, is great, not only in presenting the information desirable to those who wish to settle in the country, but also in the collection of facts neccessary to intelligent legislation concerning these lands.

In the region embraced in this survey a very small portion of the country can be redeemed by irrigation for agriculture, and no part of it can be cultivated without irrigation. It appears from the reports that less than one per cent. can be thus made available. Especial care has been given to the determination of the extent of such lands, so as to exhibit their position on the maps. These irrigable lands and timber lands, together with some small districts of coal-bearing lands, are the only parts of the country that should be surveyed into townships and sections.

Having in view economy and convenience in the linear surveys of this district, the geodetic points of the general geographic survey under the direction of Professor Powell have been carefully marked, that they may hereafter be used as datum points by the officers of the General Land Office.

Extensive coal-fields exist in the region surveyed, but, as in many other parts of the world, these coal-fields are of practical value at comparatively few places. The general characteristics of these coal-fields have been the subject of much investigation, and some very interesting and valuable results have been reached; these will appear in the final reports. The quantity of available coal is practically inexhaustible, and the mines that can be economically worked are of great number.

In the Uinta Mountains silver and copper mines have been discovered and worked by private parties. The extent of these silver and copper bearing rocks has been determined, but their value can be established only by extensive working.

Mr. G. K. Gilbert devoted much of his time to the study of the structure of the Henry Mountains, of which enough had been learned in the preceding season to warrant the belief that they embodied a type of eruption hitherto unknown. The attention given to them has been amply repaid by the elucidation of the manner of their constitution. They are volcanic, but their lavas, instead of finding vent at the surface of the ground and piling up conical mountains thereupon in the usual manner, ceased to rise while still several thousands of feet underground, and lifted the superincumbent strata, so as to make for themselves deep-seated subterranean reservoirs, within which they congealed. Over each of these reservoirs the strata were arched and a hill or mountain was lifted equal in magnitude to that which would have been formed if the lava had risen to the surface; but the material of the hill was sandstone and shale instead of hard volcanic rock. Subsequent erosion has carried away more or less completely the arching strata and laid bare many of the intrusive masses. It has revealed also a system of reticulating dikes which go forth in all directions from the main masses, intersecting the sedimentary rocks. The lava masses, the dikes, and those portions of shale and sandstone which have been metamorphosed by contact with the molten rock, are harder than the unaltered sedimentary strata which surround them, and yield to the agents of erosion more slowly. The wash of rain and streams by which the face of the surrounding country has been degraded, has been resisted by these hard cores, and in virtue of their obduracy we have the Henry Mountains. The deposits of lava are not all in juxtaposition but are scattered in clusters, and each cluster has created a mountain. Mount Ellen consists of a score of individual lava masses; Mount Pennell and Mount Hillers of one principal mass, accompanied by several of minor importance; Mount Holmes of two masses; Mount Ellsworth of a single one, with many dikes and sheets. Each of the mountains is individual, topographically as well as structurally, and together they constitute a group of mountains, not a range. Mr. Gilbert's note-books contain many sketches, by the aid of which he will be able to illustrate all the features of the peculiar types of structure.

Before commencing the main work of the season, Mr. Gilbert made an excursion in search of the outlet of Lake Bonneville, the great fossil lake of Utah. During an epoch which was probably coincident with the glacial epoch, the broad interior basin of Utah was covered by a great lake which overflowed its rim and sent an outlet to the ocean by way of the Columbia River. When the climate became gradually warmer and drier, the evaporation grew greater and the rain-fall grew less, until finally the overflow ceased and the lake began to dry away and shrink within its shores; to-day only Great Salt Lake and Sevier Lake remain, but high up on the mountain is carved the Bonneville Beach, a permanent record of the old flood-tide. The search for the point of outlet was successful, and it was found at the north end of Cache Valley, a few miles beyond the boundary of Utah, in the Territory of Idaho. The bed of the outflowing stream was traced for a number of miles. The beach-lines were seen to run quite to the pass through which the channel was cut, but beyond, on the side of the drainage of the Columbia, no trace of them could be seen.

Of no less interest was the discovery of a recent orographic movement at the western base of the Wasatch Range. A great fault runs along that base; one of the faults by which the mountains were produced. The block of the earth's crust which lies to the westward of the fault-planes was dropped down, and the block which lies to the eastward was lifted up, and from the eastward block subsequent erosion has carved the range. Along the plane of ancient movement there has been a recent movement. The mountain has risen a little higher or the valley floor has dropped a little lower, and this so recently that the Bonneville flood is ancient in comparison.

Capt. C. E. Dutton resumed this year his study of the large area of igneous rocks in Southern Utah, in the vicinity of the Sevier River, and has brought back additional information which he purposes employing in the preparation of a monograph of the entire tract. He has worked out the structure of the component features, and the approximate area of the eruptions, and is engaged in classifying the various lithologic members. The older outbreaks appear to be of early Tertiary age, (Eocene,) and to have been nearly continuous through a long period. The volcanic beds thus formed were subsequently traversed by great faults, and tables were uplifted, with deep valleys between them; the structure thus produced conforming to the general type prevalent throughout the plateau country. The degradation of these long lofty tables gave rise to conglomerate beds of great extent and thickness, which are composed entirely of volcanic materials. Captain Dutton has compared the details and arrangement of these conglomerates with the alluvial beds now accumulating in great volume in the valleys out of the waste of the adjoining tables, and finds an agreement between them so close that he ascribes the same mode of origin to both. He also finds considerable metamorphism not only in the underlying sedimentary beds (early Tertiary) but in the superposed conglomerate; and he thinks it must have occurred comparatively near the surface. The greater portion by far of the erupted rocks he classes as trachytes and trachydolerites. The rhyolitic varieties are of very limited occurrence, being found only in the vicinity of the Beaver or Tunbar Range. In the southwestern part of the field (near Panguitch) extensive fields of basalt are found. Captain Dutton distinguishes two ages of the basalt; one prior to the development of the present structural features of the region, the other subsequent to it—the former being more properly dolerite or anamesite, the latter typical basalt.

Under instructions from the Interior Department, Professor Powell and his parties have also been engaged in general ethnographic work in the Rocky Mountain Region. One of the special items in these instructions was the classification of the Indian tribes, such classification being not only of scientific interest, but of great importance in the administration of Indian affairs. For the eastern portion of the United States this work had been accomplished—first by the unofficial labors of the Hon. Albert Gallatin, and subsequently by the Hon. Henry R. Schoolcraft, as an officer of the Government; and some addition had been made to the work by various persons for scientific purposes. This work has been renewed by Professor Powell, and has been pushed with all the energy possible with the funds at his command, and a large amount of material has been collected by himself and by members of his corps, and by residents in and travelers through the country. In addition to this a large amount had been collected by the Smithsonian Institution through various channels—materials as yet unpublished. That Institution has placed all this matter in the hands of Professor Powell to be combined with his own collections. The first volume of the reports on this subject will soon be issued. It treats of the tribes of Alaska, the western half of Washington Territory, and Northwestern Oregon, and is accompanied by maps exhibiting the geographic distribution of the tribes of these regions. A second volume on the tribes of California has also been sent to the Government Printer, which will be succeeded by others as rapidly as they can be prepared.

Dr. Elliott Coues, U. S. A., is engaged on a "Report on the Birds of the Valley of the Colorado," based primarily on the collections made by the several parties under Professor Powell's direction. This report was sent to the Government Printer early in the spring, and about 200 pages have already been set up.

Mr. L. F. Ward, the botanist of the corps, assisted by several gentlemen of scientific ability in this department, has been engaged during the entire year in the preparation of a "Report on the Botany of the Valley of the Colorado," which is now nearly ready for publication.

CONCLUSION.

From the foregoing report I trust it will be evident to all interested in the prosperity of the Institution that the establishment is still successfully prosecuting the plan best adapted to realize the intentions of its founder, that its funds are in a good condition, and that its reputation and usefulness have suffered no diminution since the date of the last report.

Respectfully submitted.

JOSEPH HENRY,
Secretary Smithsonian Institution.

WASHINGTON, *January*, 1877.

APPENDIX TO THE REPORT OF THE SECRETARY.

REPORT OF PROFESSOR BAIRD ON THE CENTENNIAL EXHIBITION OF 1876.

SMITHSONIAN INSTITUTION,
Washington, January, 1877.

SIR: I beg leave to present a statement of operations for 1876 connected with the Smithsonian department of the United States Centennial exhibit, in continuation of that given in the annual report of the Smithsonian Institution for the year 1876.

At the end of the year 1875 the preparations for the exhibit referred to were in full operation, involving a great deal of arduous labor, for the purpose of having everything in readiness by the 10th of May, the date of the opening of the International Exhibition.

As originally authorized by you, the display to be made by the Smithsonian Institution was to include, first, the mineral resources of the United States; second, its animal products; and third, its ethnology.

The superintendence of the mineral section was intrusted to Prof. William P. Blake, of New Haven, a gentleman of much experience in such labors and familiarly acquainted with the mining industries of the United States generally. By visiting different localities, especially in Michigan, Missouri, and elsewhere, and by the efforts of several assistants, among them Mr. Charles M. Shepard, Mr. Howe, Professor Brodhead, and Professor Hitchcock, supplemented by an extensive and laborious correspondence, he succeeded in securing for the Institution a very full display of ores, building-stones, clays, &c.

The arrangement made with Mr. Thomas Donaldson to gather a full series of the ores of the precious metals of gold, silver and mercury from the Western States and Territories also continued to be highly productive, Mr. Donaldson personally visiting a great number of mining localities, and obtaining a full series of specimens, many of them rich in bullion and thus of very considerable commercial value.

In no case was either he or Professor Blake called upon to pay money for any article, no matter what its intrinsic value, the specimens being contributed by the owners of the mines with the understanding only that they were to receive a suitable display in the Government exhibit and subsequently in the National Museum in Washington.

Most of the material of these collections was sent directly to Philadelphia, only one of at least thirty car-loads of mineral matters being shipped from Washington.

In addition to the objects just referred to, arrangements were effected with several State commissioners for the exhibition in the Smithsonian mineral department of collections made by them to illustrate the resources of their several States, and which were delivered in the building free of cost and for the most part provided with the necessary cases and without expense to the Centennial fund. Chief among these was the exhibit of the State of Nevada, which was of very great extent and made under the supervision of Mr. Whitehill, the State geologist.

A collection from Montana, made under the direction of Mr. Woolman, came next in interest and importance. General Wilder presented a series of the ores and building-stones of Tennessee in great variety, and Mr. Joseph Wharton furnished a large quantity of raw material and finished products connected with the nickel industry. Under the supervision of Dr. E. R. Beadle, Dr. Koenig, and Mr. Wilcox, a very valuable loan collection of the principal minerals of the United States formed part of the Smithsonian exhibit.

The animal division was under the special charge of Mr. G. Brown Goode and included the subject of the fisheries of the United States, for which special provision was made in the congressional appropriation.

Mr. Goode prepared, with great labor, a classification of the objects necessary to constitute such an exhibition, which was printed by the Interior Department as No. 6 of the Bulletins of the National Museum and widely circulated.

In addition to the objects purchased or presented to this series, several very valuable collections were lent by various parties. Among them may be mentioned a great variety of nets by the American Net and Twine Company of Boston; an extensive series of apparatus used by the angler, by Messrs. Bradford & Anthony, of Boston; of North American furs, by Messrs. Charles Herpich & Co., of New York; polished Unio shells from Dr. Miller and Mr. Schaffer, of Cincinnati, &c.

Here, as in the case of the minerals, the donations and loans were so numerous as to render it impossible to mention them in a brief report like the present.

The ethnological exhibit was made under the auspices of the Indian Bureau of the Interior Department, the funds necessary for the purpose being supplied from its share of the Centennial appropriation.

The preparation for the exhibition and the arrangement of the collection were under the direction of Dr. Charles Rau, assisted by Mr. F. H. Cushing. The collections in the field were made by Messrs. James G. Swan, in Alaska and Washington Territory; by Mr. Stephen Powers, in California and adjacent States; by Major J. W. Powell, in Arizona, Utah, and Colorado; by Messrs. Stephen Bowers and Paul Schumacher, on the coast of the Pacific and California.

A large number of loans, especially of stone implements, &c., were made by various gentlemen throughout the country, who were interested in rendering this portion of the general exhibit complete.

The Government building was completed and turned over to the executive board on the 1st of March, although the Smithsonian division was occupied by Professor Blake prior to this with a portion of the mineral display.

The shipments to Philadelphia from Washington began on the 20th of April, and a very large force was necessarily engaged for a time in the Government building in putting up the cases, for the most part manufactured in Washington, and in unpacking and arranging the collections. The contents of eighteen cars were loaded in Washington, forwarded to Philadelphia, and unpacked, between the 20th of April and the 1st of May, several car-loads following in the latter month. The total number of car-loads sent from Washington amounted to twenty-two, while nearly forty full or partly full loads were sent from other directions, principally containing minerals.

In arranging the various specimens in the Government building, Professor Blake, for the mineral section, was assisted by Mr. Donaldson, Mr. Adams, Mr. Thompson, and, for a time, by Mr. Draper.

The animal and fishery sections were placed in order by Mr. Goode, aided by Messrs. Chester and Brown, and the ethnological by Dr. Rau, assisted by Mr. Cushing; all the departments having many laborers and other assistants.

On the 10th of May, the opening day of the International Exhibition, the greater part of the Smithsonian and Fish Commission collections was in place, although still requiring some subordinate arrangement; and it may here be stated, generally, that the Government exhibit was far more nearly ready on that day than any other in the Centennial Exhibition—those of the War and Navy Departments being entirely in order. By the 1st of June, all the collections of the Institution were in place, the specimens labeled and everything in satisfactory condition.

In obedience to your instructions, I left Washington on the 31st of May, to take direct charge of all the branches of the Smithsonian and Fish Commission divisions, assisted in their respective sections by Messrs. Blake, Goode, and Rau. Mr. Goode, however, was unfortunately soon obliged to leave, in consequence of the illness caused by overexertion, and his place was not supplied.

Numerous collections of various kinds were added throughout the season of the exhibition, partly in continuation of the special researches instituted by the Smithsonian Institution and the Indian Bureau, and partly by individual contributions. A very attractive feature of the Fish Commission section was a succession of fresh fish, supplied by Mr. E. G. Blackford, the well-known fish-dealer of Fulton Market, New York, who made special arrangements to secure all the varieties of American food-fishes, sending them in ice to the Government building and delivering them there without any charge whatever. Here they were shown in two immense refrigerators—one contributed by Mr. Alegretti and one by Mr. Banta, each having its peculiarities. Here were exhibited day by day not fewer than two hundred varieties of American fishes. Some of the fish were kept on exhibition in a frozen condition during the entire period of the Centennial display.

My own work I found very arduous, in consequence of the large amount of correspondence, the number and complexity of accounts, and the constant stream of visitors. To this was added service on two of the groups of judges—one that of the fisheries and the other the supplementary group, instituted toward the close of the exhibition, to take cognizance of exhibits which claimed consideration for award from having been overlooked when the first series of judges prosecuted their labors.

It may be readily imagined that, however arduous the duties of the position assigned me at the Centennial, the associations were extremely agreeable, in view of the large number of intelligent and scientific men among the judges, both American and foreign, and the gentlemen connected with the several commissions with whom I was brought in contact. The relations to the United States Centennial Commission were also extremely pleasant, the director-general, the president, and the officials generally doing all in their power to facilitate the labors of the Government board.

It is with much satisfaction that the members of the executive board have been able to report to their respective chiefs the fact that the collective exhibition made by the Government, under their charge, was considered the most satisfactory and instructive display of all those shown at the International Exhibition, both as respects extent and variety, and the thoroughly systematic and convenient arrangement and labeling of the collections. A printed catalogue was contemplated and the manuscript for the same prepared, but the Centennial appropriation would not admit of the cost. An application was therefore made to Congress for an order to print this catalogue, but failed to receive consideration in the closing hours of the session.

The exhibition closed on the 10th of November, in accordance with the original plan, or in six months from its opening, and, as is known to every one, it continued to increase in interest until the final day. The unusual heat of the summer deterred many persons from visiting it at that season; but with the cooler weather of the late summer and autumn the throng was immense, and the general result, both as to the number of visitors and the receipts, was unexampled in the history of similar exhibitions.

Some time before the close of the exhibition intimations had been made by numerous exhibitors, both foreign and domestic, of a design to make various donations of material to the United States; but the exact magnitude of these accessions to the collections displayed was far from being anticipated. As it proved, not only did many private individuals contribute their collections to a greater or less extent, but objects from the exhibits of various States were presented, notably from those of Michigan, Ohio, Indiana, Tennessee, &c., in addition to the collections from Nevada, Utah, and Montana, already mentioned as included in the Government series. It was, however, by foreign nations that the most important donations were made, their commissioners, with few exceptions, presenting either the whole or a large part of their animal-, vegetable-, and mineral-, and to a considerable extent their industrial exhibits. An accompanying list expresses in general terms the character of the objects received from the different parties, but no adequate idea can be formed of the whole until the collection is re-arranged in a suitable building in Washington.

The suggestion of the President of the United States that acknowledgment be tendered by Congress to the foreign commissions which have made such remarkable donations to the people of this country is one eminently worthy of consideration.

No provision was made by Congress for the reception of the new material referred to, beyond an appropriation, to the Smithsonian Institution, for the repair and fitting up of the Armory building to receive them in Washington; and as the Institution is only required to take charge of "objects of nature and art, of foreign and curious research, of natural history, mineralogy and geology belonging to the United States," *when the same shall be "in the city of Washington,"* it was a matter for consideration to what extent it would be proper to use the funds appropriated by Congress for the Centennial Exhibition in receiving and taking charge of such objects.

In view of their relation in most cases to subjects covered by the Smithsonian exhibit and of the manifest discourtesy of rejecting and refusing to receive such articles, I asked and obtained your permission to take charge of them, and immediately set to work a large force in transferring them from the various buildings to the Government building. This force was engaged in the transfer almost uninterruptedly from the 10th of November, the closing day of the exhibition, until the middle of February. The expenses of cartage alone to the Government building exceeded a thousand dollars, some of the specimens being of great magnitude and weighing several tons.

Simultaneously with the employment of the transfer parties, another force was occupied in packing the collections in preparation for shipment, the additions thus made being estimated to require from forty to sixty freight-cars for their accommodation.

Reference has already been made to the expressions of interest in the Government exhibit and in its transfer in bulk to Washington and reproduction there. This idea was broached at an early period and its importance urged by many influential newspapers.

The National Academy of Sciences at its meeting in October directed its president to memorialize the President of the United States on this subject, and, this having been done, His Excellency directed that all operations looking toward the transfer of the collections to Washington be suspended until Congress might take such action as it deemed proper in regard to the subject. This order was subsequently modified by allowing the removal to Washington of such objects as were needed for the use of the Departments and all such specimens as were liable to be injured by the cold and dampness which prevailed throughout the building after the 10th of November.

In view of the fact that the building, having been sold, was deliverable to the purchaser on the 1st of March, on the 19th of January, 1877, a final order was issued by the President directing the transfer of all the articles to Washington, there to be stored in some suitable place or places, pending congressional action.

I remained in direct charge of the operations of receiving, packing, &c., until the 9th of December, when, in obedience to your instructions, I returned to Washington and left Mr. Daniel Leech, of the Smithsonian Institution, to direct future operations, assisted by Messrs. Chester and Brown, the mineral collection still remaining under Professor Blake's special administration. These gentlemen have been diligently occupied in the interval in packing the objects and in forwarding them to Washington as fast as suitable cars could be obtained, and it is expected that the entire series will be in Washington by the 10th of February.

It was extremely fortunate that Congress gave to the Institution the use of the armory building, an edifice 100 by 50 feet in dimensions, and with four floors, of 5,000 square feet each, as without it it would have been entirely impossible to provide for one-fourth of the collection. It was intended originally that the armory should serve as a supplement to the Smithsonian building by exhibiting on two of its floors the fishery and mineral collections, but it was soon found that any idea of a display there must be abandoned and the building used exclusively for the storage of objects in boxes. It is now being rapidly filled on all its floors in this way, and any attempt at an exhibition of its contents must be deferred until a suitable building can be constructed for the purpose.

An extension of the National Museum by the construction of additional wings, or other buildings, in connection with the Smithsonian edifice has long been in contemplation, as for many years it has been impossible to show many of the most interesting objects belonging to the United States for want of suitable space. The Centennial collections, however, being added to the former stock, has precipitated the crisis in this respect and rendered it necessary that some special arrangement be made at an early day for the accommodation of the entire series.

The entire capacity of the Smithsonian building is now 25,000 feet of floor space. The collections exhibited by the Institution at the Centennial, covered about 34,000 feet of floor. The donations at the close of the exhibition will certainly require 24,000 feet, while articles stored in the basement, and never shown at all, call for at least 20,000 feet.

It is thought, however, that these additional collections may be condensed into a space of, perhaps, 50,000 feet, although the aggregate space already mentioned would be much better suited to the exigencies of the case, and it is therefore to be hoped that Congress will, at an early day, take action in reference to a new building, which, of course, will be most conveniently placed in connection with the Smithsonian edifice.

This should be constructed as cheaply as possible, consistent with the demand for space and protection against the elements and fire. It is thought that by laying a concrete floor on the ground, using brick walls and piers and a roof with iron beams, and wooden sheathing covered with tin, these requirements will be most readily met. Several plans have been proposed for this building, some one of which it is hoped will find favor and be adopted.

In a series of accompanying papers, I beg to present a general account of the Government exhibit, a statement of the contributions from foreign governments, and a separate list of the more important contributions of mineral objects from American sources.

The alphabetical list of contributions to the National Museum for the year 1876, will also show the many smaller donations that have been made to its several departments.

I have the honor to be, very respectfully,

SPENCER F. BAIRD,

Representative of the Smithsonian Institution and of the Department of Food-Fishes in the Government Centennial Board.

Professor JOSEPH HENRY,

Secretary Smithsonian Institution.

GENERAL ACCOUNT OF THE GOVERNMENT CENTENNIAL EXHIBIT; BY PROFESSOR BAIRD.

Appropriations by Congress in acts of March 3, 1875, *and July* 19, 1876.

	March 3, 1875.	July 19, 1876.	Total.
War Department	$133, 000	$18, 500	$151, 500
Navy Department	100, 000	....	100, 000
Interior Department	115, 000	15, 000	130, 000
Treasury Department	5, 000	14, 000	19, 000
Post-Office Department	5, 000	....	5, 000
Agricultural Department	50, 000	....	50, 000
Smithsonian Institution	67, 000	21, 000	88, 000
United States Commission of Food-Fishes	5, 000	5, 000	10, 000
For show-cases, shelving, stationery, &c	25, 000	....	25, 000
	505, 000	73, 500	578, 500

PREPARATION FOR THE EXHIBITION.

Erection of building.—A committee of the board of the respective Departments, was appointed to take into consideration all the matters relating to this building, and to consider plans for the same; and from several offered them, that of an edifice in the form of a cross, designed by James H. Windrim, of Philadelphia, was selected. The floor of this occupied 102,840 square feet, of which 20,840 was taken up by passages, leaving a space remaining of 82,000 square feet for exhibition purposes. It was completed and ready for occupation March 1, 1876, on which date it was accepted by the board. The space assigned to each Department was as follows:

	Feet.
War Department	11,200
Navy Department	10,400
Treasury Department	3,000
Post-Office Department	3,800
Interior Department	20,600
Agricultural Department	6,000
Smithsonian Institution	20,600
Fish Commission	6,000
	81,600

The original contract for the cost of this building was $67,201.61, but subsequent changes somewhat increased the amount. These, with other expenses, such as grading the grounds, &c., made the total amount to be deducted from the available fund, and divided *pro rata* among the various Departments, with the exception of the Treasury and the Commission of Food-Fishes, about $94,000, leaving about $411,000 for the actual purposes of the display.

The building was entirely of wood, and of course liable to damage from fire. A careful guard was, however, maintained, and no accident of any kind occurred during the exhibition.

EXHIBIT AS MADE.

Completeness on opening-day.—Although the time at the command of the board for the preparation of the exhibit was short, and the amount of money appropriated to carry out the plans of the several departments was considered by them insufficient for the purpose, on the opening-day of the exhibition most of the articles were in their places, this being especially the case with those of the Army and Navy; and the remainder were ready within the course of a few weeks later. In this respect the Government display was in advance of those in the other buildings, the internal arrangements of which were more or less incomplete for a long time after the 10th of May.

Summary of exhibits in the different sections.—The collections, as finally arranged, consisted essentially of the following elements:

A.—*The War Department.*

1. *The Signal-Service Bureau.*—In this was shown the apparatus of the Signal-Office proper, with its field telegraph and wagons, instruments, &c., and that of the weather-observation division, with its self-registering and other meteorological apparatus. Here observations were made and recorded, and a copy of the daily weather bulletin posted.

2. *The Ordnance Bureau.*—Here were shown all the machinery, in working operation, for the manufacture of cartridges and of the Springfield rifle, together with a series of models of ordnance of different patterns, shot, shell, &c., and outside the principal building was a laboratory for illustrating the methods of testing ordnance and powder.

3. *The Quartermaster's Department.*—This displayed specimens of the uniforms of soldiers at different periods in the history of the American Army, the horse-equipments, tents, blankets, &c., as also a veterinary display illustrating the diseases of horses' feet.

4. *The Engineer Bureau.*—Here were shown models of river and harbor improvements, including that of the excavation at Hell Gate, samples of maps and charts issued by the bureau, &c.

5. *The Medical Department.*—The exhibit of this department of the Army consisted of a model hospital of the size and equipment of those of usual construction at military posts. Here were the appliances used for keeping and transporting sick and wounded on land and water, the medicines used in the Army, surgical apparatus, and photographs and engravings illustrating the surgical history of the Army, &c.

B.—*The Navy Department.*

1. *Navy Ordnance Bureau.*—In this section were exhibited the different large and small arms used by the Navy at present and in the past, illustrations of the torpedo system, &c.

2. *Bureau of Steam-Engineering.*—This embraced specimens of the different forms of engines used in naval vessels.

3. *The Bureau of Construction and Repair.*—This exhibit included two large working models of the Antietam, one fifty feet long, and serving as a trial-ship for the cadets at Annapolis; also a model of a newly-constructed monitor, and a full-sized monitor-turret, with its guns, was displayed outside of the building.

4. *Bureau of Yards and Docks.*—This showed various models of the different dry-docks belonging to the United States Navy.

5. *Bureau of Medicine and Surgery.*—This presented an exhibition of the various drugs, medicines, food, &c., as prepared for use on shipboard, together with all the equipments of naval hospitals, models of hospital-ships, &c.

6. *Bureau of Equipment.*—Here was shown ships' galleys, boat-stores, uniforms of the Navy in different periods of its history, specimens of rope, bunting, signals, and various patterns and forms of flags.

7. *Bureau of Hydrography.*—The most interesting portions of this was the collection of articles illustrating the various polar explorations of Kane, Hayes, and Hall; also specimens of charts prepared by the Hydrographic Office, compasses, sounding apparatus, and the apparatus used in the observations of the transit of Venus by the American parties.

C.—*Treasury Department.*

1. *The United States Coast Survey, and Bureau of Weights and Measures.*—In this were shown a series of the weights and measures of the United States, and the very complete apparatus used in the measurement of base-lines for surveys. A series of the reports of the office, and of its maps and charts, was also displayed.

2. *Light-House Board.*—In this were shown the different lanterns used for purposes of illumination; the different oils, wicks, &c.; models of light-houses, light-ships, &c. Outside of the building was erected an actual light-house, in full working order, and lighted every night; as also a fog-trumpet or syren of enormous power, capable of being heard at a distance of many miles. This was used to indicate the time daily for the opening and closing of the Centennial Exhibition.

3. *Revenue Bureau.*—In this were shown the specimens of all the forms of revenue-stamps, and the apparatus used in gauging, &c.

4. *Bureau of the Supervising Architect of the Treasury.*—In this, models of various public buildings were shown.

Specimens of United States currency, bank-notes, &c., were also shown by the Treasury Department, as also a complete life-saving station, with boats, &c.

D.—*Post-Office Department.*

In this portion of the building was held the Centennial branch of the Philadelphia post-office, fully meeting the needs of the Centennial Exhibition, and kept up several weeks after the close. Here were seen in operation machines for making stamped envelopes, samples of locks, bags, &c., and two first-class railway postal cars.

E.—*Department of the Interior.*

1. *Bureau of Education.*—In this division were shown models of school-houses from different parts of the country and different periods in our history; school-furniture; apparatus for educational purposes; samples of school-drawing and articles used in object-teaching; illustrations of the progress of the Indian tribes in education and civilization.

2. *Census Bureau.*—This presented the original schedules of the census of 1790, 1840, and 1870, illustrating the progress of the country by the comparative magnitude of the records.

3. *The Patent-Office.*—In this was shown a selection of models from the Patent-Office, illustrating the more important stages of develop-

ment in the industrial and economical arts from the beginning of the Patent-Office system to the present day, as also a complete set of publications of the office.

In connection with this display were arrangements for illustrating the actual methods by which patents are issued in the United States, from the first application for the purpose to its entire completion. In the Patent-Office section were also shown a variety of historical relics, including articles of clothing once owned by Washington, as well as his camp furniture and equipage.

4. *The General Land-Office* exhibited its series of maps, especially one of very large size, constructed expressly for the purpose, and showing the present condition of the land-office system over the whole United States.

5. *The Indian Bureau.*—This display, which was made in co-operation with the Smithsonian Institution, contained illustrations of the aboriginal inhabitants of the United States, both ancient and modern; specimens of their stone implements and pottery; their weapons and domestic utensils; their ornaments and articles of religious observance, &c.

6. *Pension Office.*

7. *Geological Surveys of the Territories.*—Here were exhibited models in relief of areas of the western country, and of ancient ruins, transparent and other photographs of scenery, antiquities, and Indians, books, maps, charts, &c.

F.—*Department of Agriculture.*

1. *Chemical section.*—In this were shown the soils, rocks, marls, fertilizers, agricultural products and their derivatives, samples of food, such as flour, sugar, &c., products of dry distillation of wood, preparations of oils, &c.

2. *Natural-history section.*—This exhibited birds, insects, and other animals injurious or beneficial to the farmer, and included a series of 300 engraved plates to illustrate a work on the economical entomology of the United States; also models of different fruits and vegetables, and sections of 400 species of North American woods, with their leaves and fruits, as well as a series of vegetable fibers, with their applications.

3. *Statistical section.*—In this were shown charts and maps of the farm-lands, the distribution of forests, and the regions suitable for the cultivation of various staples. There were also many engravings of agricultural colleges, &c.

G.—*The Smithsonian Institution.*

This illustrated, first, the operations of the Institution itself; second, that of the National Museum of the United States under its charge.

1. *The Smithsonian Institution.*—This display contained a full series of all the publications of the Institution and charts illustrating its system of international exchanges, with a set of large charts, showing the mean temperature and the rain-fall in the United States.

2. *National Museum, under the direction of the Smithsonian Institution.*—In the museum section were shown collections illustrating the economical mineral wealth of the United States, in a series of ores of the precious and baser metals and their metallurgy, including specimens of the metals and their simple applications; the materials used in the manufacture of glass, such as sand, soda, &c.; and the earth and clays, with their applications in tiles, terra-cotta, bricks, and pottery; the different varieties of coal, petroleum; samples of the principal building stones, as marble, granite, &c.

The animal section contained, first, representations of the animals of the United States of economical importance to the country, as furnishing food, ivory, bone, leather, glue, furs, bristles, oil, &c.; second, the apparatus by which these animals are pursued and captured; third, the means by which they are utilized for the wants or luxuries of man when taken; fourth, specimens of the products of such utilization and their simple applications; and, fifth, the methods by which they are protected and multiplied.

H.—*The United States Fish Commission.*

In this was shown a series of models in plaster or *papier-maché* of the principal fishes and cretaceans of the United States, and photographs and original drawings of the same, as furnishing oil, bone or manure, together with the apparatus of pursuits and capture; models of boats of different styles of construction, and special illustrations of the whale-fishery. Also the methods of fish-culture, in illustrations of hatching-boxes, carrying-vessels, models of fish-ways, &c. This display and that of the animal department of the Smithsonian exhibit were more or less united, and illustrated not only the methods and appliances of civilized man in this connection, but also those of the American savage.

Public opinion in regard to the Government exhibit.—As already remarked, the officers in charge of the Government exhibit were unable to make it as complete as they had hoped, on account of the reduced appropriation for the purpose; but as it was, it was considered by all visitors as decidedly the best part of the International Exhibition, in view of the extent and exhaustiveness of the collection and the method and order of its display.

No special catalogue of the Government exhibits was printed, authority not having been obtained from Congress for the purpose, although a very full catalogue had been prepared.

The building was constantly the resort of intelligent visitors from all parts of the world, and a great many critical reports have been published already in foreign journals in regard to this display. Professor Archer, one of the chief commissioners from Great Britain, in a lecture recently delivered before the Society of Arts in London, uses the following language, in speaking of the United States Government building and its annexes:

"This group consisted of a very large edifice, in the form of a cross, erected by the United States Government at a cost of $60,000, and, in addition, a laboratory, for illustrations of arsenal work, and a model military hospital, which was of great practical utility during the exhibition. Within the chief building was displayed most interesting and instructive collections, illustrative of the work of the Smithsonian Institution, and the general and geological surveys of the States, the mineral, zoological, and botanical collections connected with those surveys, and also most important ethnological and prehistoric collections. The great collection of food-fishes of America, made for the fishery commission by Professor Baird, with the appliances for catching and preserving fish; also series illustrating the various naval and military weapons and engines, and machinery for arsenal work; and, lastly, a complete display of all the applications in the postal department of the States. The general arrangement of the contents of this large building, covering about two acres, was most satisfactory, and had been carried out under the most competent scientific supervision; hence it was felt to be the most instructive portion of the Centennial Exhibition. It brought into full view a great mass of the intellectual work of some of the greatest of American workers in the fields of science."—*Journal of the Society of Arts, December* 22, 1876.

These suggestions were based upon the exhibit as actually made and which closed with the expiration of the Centennial Exhibition, on the 10th of November.

DONATIONS TO THE UNITED STATES GOVERNMENT.

After the close of the Exhibition a new element was introduced into the question of the transfer of the Government collections to Washington and their arrangement for inspection and study, namely, the donation to the United States of many objects or entire collections, that had been displayed elsewhere in the Exhibition than in the Government building. These were derived from two sources:

1st. From American State commissions and private exhibitors, by whom much material of great value was presented and tending to fill up important blanks.

2d. From the commissions of the several foreign governments participating in the International Exhibition of 1876.

The experience of previous expositions had indicated the probability of contributions from the latter source, and to meet the expected emergency Congress at its last session granted the Armory building to the National Museum, and made an appropriation for the purpose in the following words:

"For repairing and fitting up the so-called Armory building, on the mall, between Sixth and Seventh streets, and to enable the Smithsonian Institution to store therein, and to take care of specimens of the extensive series of the ores of the precious metals, marbles, coals, and numerous objects of natural history now on exhibition in Philadelphia, including [any] other articles of practical and economical value, presented by various foreign governments to the National Museum, four thousand five hundred dollars: *Provided*, That the said sum shall be expended under the direction of the Smithsonian Institution."

The contributions from the States were of very great value; Nevada, Utah, Montana, Tennessee, &c., presenting most valuable series of their ores, while an aggregate of much magnitude was received from individuals; minerals, metals, ores, building-stones, coals, pottery, &c., all being included. It was, however, from the foreign commissions as above referred to that the greatest mass was derived, so that, although the gift of some articles was anticipated, the members of the Government board were not prepared for the wholesale donation of by far the greatest portion of the collective exhibits made by foreign nations, as well as those of many of their individual exhibitors. Among these may be mentioned specimens of mining and metallurgy, ores, metals, combustibles, building-stones, earths, clays, tiles, terra-cotta, and pottery; vegetable products, as samples of woods, fibers, seeds, medicinal plants, &c., furs, skins, gelatine, samples of industrial products in the way of woven and plaited fabrics, objects in metal, wood, glass, earthen wares, illustrations of manners and customs, &c.

List of countries from which donations were received.—The nations from which were received the collections in question are the following:

Argentine Republic.
Austria.
Africa, (Orange Free State.)
Belgium.
Brazil.
Chili.
China.
Egypt.
France.
German Empire.
Hawaiian Islands.
Japanese Empire.
Mexico.
Netherlands.
Norway.
Peru.
Portugal.
Russia.
Spain.
Philippine Islands.
Sweden.
Switzerland.
Tunis.
Turkey.
United Kingdom and Colonies.
Bermuda.
Canada.
New South Wales.
New Zealand.
Queensland.
South Australia.
Tasmania.
Victoria.
Venezuela.

The commissions which are not included in this list had nothing at their disposal, their exhibitions consisting either purely of private material reclaimed or otherwise disposed of by their owners, or, as in the case of several British colonies, of articles borrowed from the colonial museum in London and necessarily returned there.

Assignment of collections received.—While no special authority had been given by Congress to receive these articles, it was not considered proper to refuse them, and they were accordingly taken charge of by the several departments of the Government to which they were most nearly related. An exhibit of the iron, chain-cables, cordage, &c., of the naval department of Russia was received by the representatives of the Navy Department. To the Bureau of Education was delivered everything of an educational character. The Department of Agriculture received the articles belonging to the vegetable kingdom, such as sections of wood, fibers, grains, seeds, &c., while articles belonging to the mineral and animal kingdoms, and as illustrative of the manners and customs of the people, were taken by the Smithsonian Institution, and objects relating to the fisheries by the United States Fish Commission.

Accompanying communications from some of these departments give in fuller detail the character of these donations. Suffice it to say, that so far as the Bureau of Education, the Department of Agriculture, the Smithsonian Institution, and the Commission of Food-Fishes are concerned, the collections promise to exceed in magnitude their own Centennial exhibitions

PROPOSED TRANSFER OF THIS COLLECTION TO WASHINGTON.

General feeling on the subject.—The interest in the exhibition of the Government very naturally suggested to many the importance of transferring it to Washington and maintaining it in its original form, and numerous suggestions and earnest appeals to that effect have already appeared in the public press. This feeling met with special expression in a resolution of the National Academy of Sciences, at its session in Philadelphia in October; and in compliance with its instructions, Professor Henry, its president, transmitted to the President of the United States the following communication:

"SMITHSONIAN INSTITUTION,
"*Washington, D. C., November* 13, 1876.

"*To His Excellency the President of the United States:*

"SIR: I have the honor to inform you that at a meeting of the National Academy of Sciences, held in October last, the following preamble and resolutions were unanimously adopted:

"'Whereas the members of the National Academy of Sciences have been greatly impressed by the extent, rarity, and richness of the truly national collection contained in the Government building at the Centennial Exhibition, and considering the great importance and lasting interest with which the people of the United States must regard this collection: Therefore,

"'*Resolved,* That in the opinion of the Academy the Government collections as a whole should be transferred to Washington, and there preserved in an appropriate building for perpetual exhibition.

"'*Resolved,* That the Academy entertains the hope that the President of the United States will favor the foregoing proposition; that he will delay the dispersion of the exhibit from the several Executive Departments until Congress has assembled, and that he will recommend to that body to provide for the transfer of the Government collection to the city of Washington, and for its subsequent permanent support.'

"In transmitting these resolutions to your Excellency, I beg leave, in favor of the proposition, to suggest, first, that the exhibit would form a fitting memorial of the centennial condition of the country; second, that it would illustrate in a striking manner the appliances used by the Government in carrying on its various and complex operations; third, that it would be a repository in which the natural resources of each State would be exhibited; fourth, that it would give information, in one view, of importance to the statesman, legislator, scientist, educator, and the capitalist of our own and of foreign countries; fifth, it would be of interest to the intelligent public at large, and would meet the approbation of all who regard the prosperity of the country, and take pride in the condition of the national capital.

"In conclusion, it may not perhaps be improper to remark that I do not advocate this proposition for the purpose of extending the power and influence of the Smithsonian Institution. On the contrary, I think the exhibit should be made a truly national one, and be immediately under the control of the Government.

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

"JOSEPH HENRY,

"*President National Academy of Sciences.*"

Economical value of the collection.—Embracing as these donations do the essential portion of the displays of foreign nations, such as their natural products, general industries and educational and scientific methods, &c., it is clearly evident that the element of the Centennial Exhibition of most importance to the American people, has thus been left to it, in the closing of the Centennial, and if properly administered must conduce in a very great degree to the material and mental advance of the nation. By re-arranging it in a systematic manner, in connection with the articles already shown, a most instructive and important museum can be made available to the people of the United States. We are assured that no such collection as this is to be found in any part of the world; and it is very doubtful whether it can ever again be reproduced, as many of the nations represented at the Centennial have intimated their intention of not taking part in the Paris or any future exposition.

Distribution of duplicates.—As might be expected, a large amount of duplicate material accompanies these donations to the United States from American and foreign sources, which, when a final arrangement is accomplished, can, if Congress so direct, be distributed to various educational and industrial establishments throughout the United States.

Commercial value.—The expenditures of the United States, for an exhibition lasting but six months have amounted to nearly $600,000. The donations from our own States and individuals, tending to fill up some of the gaps and complete the American display, which an insufficient appropriation interfered with, and those from foreign nations which have been given to the United States, can hardly be considered as overvalued at $400,000, and we therefore have an aggregate of property, in value, of at least a million of dollars to provide for.

Future increase of collections.—Promises have been made by most of the foreign commissions to complete any portion, illustrating the natural products and industries of their respective countries whenever the arrangement of the collection shows the deficiencies.

Action of the President in regard to transfer.—In view of the magnitude of the collections thus acquired by the United States, and the inadequacy of any present provision for their transfer to Washington, and their arrangement here, as also in view of the urgency of the appeal of the National Academy of Sciences, the President, under date of November 17, 1876, issued an order forbidding the removal of the articles in the Government building until some arrangement could be made in regard to them. This order was subsequently modified by allowing such objects as were required for the use of the Government in Washington or elsewhere, to be transferred, as also such as were liable to decay or injury by remaining in a building exposed to cold and dampness. The greater part of these articles are now stored in the Government building at Philadelphia, waiting some action on the part of Congress.

Demolition of Government Centennial building soon required.—As the contract made by the park commission with the Centennial Commission requires the removal of all the buildings within 60 days of the close of the exhibit, it is necessary to take speedy action on this subject; and if Congress does not see fit to erect a building at the present time for the proper display of the collections, measures must at any rate be authorized for their removal to Washington, and their storage in some safe place, as the appropriations made to the Government board did not contemplate these foreign and domestic donations in their enormous aggregate, and are entirely inadequate to handling them. The articles of this character, in charge of the Smithsonian Institution alone, will, it is stated, fill fifty freight-cars to their utmost capacity, in addition to the collections prepared by the Institution directly for the exhibition, and moved from Washington to Philadelphia in the spring of 1876.

As the Government building embraced an area of about 100,000 square feet, it is evident that one of less magnitude would not suffice for the reproduction of an exhibit of the original and acquired material.

INTERNATIONAL EXHIBITION, PHILADELPHIA, 1876.

The United States Centennial Commission has examined the following reports of the judges and accepted the following reasons, and decreed an award in conformity therewith.

FRANCIS A. WALKER,
Chief of the Bureau of Awards.

Given by authority of the United States Centennial Commission.

A. T. GOSHORN,
Director-General.

J. R. HAWLEY,
President.

J. L. CAMPBELL,
Secretary.

REPORT ON AWARDS.

I.—PUBLICATIONS, COLLECTIONS IN NATURAL HISTORY, AND ARCHAEOLOGY.

TO THE SMITHSONIAN INSTITUTION, WASHINGTON, D. C.

"The importance of the scientific work done by the Smithsonian Institution and the great value of its publications are everywhere acknowledged. The exhibits representing its museum, now known as the 'National Museum,' are very extensive and of very high merit. This statement is made, not without regret that the funds of the Institution are inadequate to a yet larger work in the many important fields it has occupied, and in the hope that, to the end of such enlargement of its labors, the Government of the United States will early relieve the Institution of the necessity to use any portion of a fund consecrated to 'the increase and diffusion of knowledge' for the maintenance of a museum intended primarily to represent the resources of the United States."

II.—MAPS, BOOKS, AND COLLECTION OF THE ANIMAL AND MINERAL PRODUCTS OF THE UNITED STATES.

TO THE SMITHSONIAN INSTITUTION, WASHINGTON, D. C.

"Its successful efforts for the increase and diffusion of knowledge, as shown by its researches, publications, and system of international exchanges, and its display of the animal and mineral resources of the United States."

III.

TO THE SMITHSONIAN INSTITUTION, NATIONAL MUSEUM, AND COMMISSION ON AMERICAN FOOD-FISHES, WASHINGTON, D. C.

"For a very superior scientifically and practically arranged display of the vast natural resources of the United States, embracing animals beneficial or injurious to man, means of pursuit and capture, means of utilization, animal products and their applications, protection and culture of useful animals. Collections illustrating the mineral wealth of the United States, systematically arranged. Geological maps and publications and collections of ethnological objects of the greatest interest for this branch of science."

IV.—ORES AND MINERALS.

TO THE SMITHSONIAN INSTITUTION, WASHINGTON, D. C.

"Commended for a very full and instructive collection of the ores and minerals of the United States, and for the admirable order and arrangement of the exhibit."

V.—COLLECTION OF BUILDING-STONES.

TO THE SMITHSONIAN INSTITUTION, WASHINGTON, D. C.

"For the magnitude of the exhibit and the excellent quality of many of the marbles, granites, &c., exhibited."

VI.—SKINS AND FURS.

TO THE SMITHSONIAN INSTITUTION, NATIONAL MUSEUM, WASHINGINGTON, D. C.

"This Institution, which in a collective exhibit shows the most complete and systematic display of the various series and grades of excellence in crude, dressed with long hairs, plucked, and dyed fur-seals of Alaska and South Pacific, as well as other furs.

"We consider also as a duty to mention the names of the gentlemen who selected their finest specimens and placed them at the service of the Institution. Among them we mention Mr. Chas. A. Herpich, of New York; M. Treadwell and Company, of Albany; Mr. Bowsky, of New York; and Renfrew and Company, of Canada.

"It is very interesting to see how far this industry was brought in the United States, and as a show for public instruction the Smithsonian exhibit is a true success."

VII.—FOOD-FISH.

FOOD-FISH COMMISSION OF THE UNITED STATES, WASHINGTON, D. C.

"For its unique character, its scientific arrangements, the completeness of its illustrations, and its economical value."

VIII.—CASTS OF AMERICAN FISHES IN PLASTER OF PARIS AND PAPIER-MACHÉ.

TO THE SMITHSONIAN INSTITUTION, FOR JOSEPH PALMER, WASHINGTON, D. C.

"For the most faithful representation of the fish on the American coast. These casts, which number four hundred and eight (408,) constitute the largest and most perfect collection heretofore made, as a perfect illustration of the shape, form, and appearance of American fish."

IX.—COLLECTIVE EXHIBIT OF PHOTOGRAPHS OF AMERICAN FOOD-FISHES.

TO THE SMITHSONIAN INSTITUTION, FOR T. W. SMILLIE, WASHINGTON, D. C.

"For great comprehensiveness of exhibit and excellence, illustrating the fish of America."

X.—COLLECTION OF WATER-COLOR SKETCHES AND OIL PAINTINGS (ON PLASTER CASTS) OF FISH OF NORTH AMERICA.

TO THE SMITHSONIAN INSTITUTION, FOR J. H. RICHARD, WASHINGTON, D. C.

"For exceeding truthfulness in the coloring of the plaster casts of fish, and for the pains-taking labor and artistic effects."

ADDITIONS TO THE COLLECTIONS OF THE NATIONAL MUSEUM, IN CHARGE OF THE SMITHSONIAN INSTITUTION IN 1876.

Abbott, C. C. Jasper nucleus, perforator, pipe-bowl, and bowl of variegated slate, from New Jersey.

Adams, S. N. Specimens of wulfenite, from Nevada.

Aiken, Charles E. Specimens of Abert's squirrel (*Sciurus abertii*), common skunk (*Mephitis mephitica*), swift fox (*Vulpes velox*), badger (*Taxidea americana*), and prairie wolf (*Canis latrans*) in the flesh, and 5 buffalo-skins (*Bison americana*), from Colorado. (Purchased.)

Alaska Commercial Company. One box seal-skins, series of unplucked, plucked, plucked and dressed, and plucked, dressed and dyed seal-skins.

Allen, J. & S., Walpole, Mass. Two series of linen fishing-lines.

Allen, J. J. & Sons, Philadelphia, Pa. Sample of soluble marine guano.

Alden Sea-Food Conpany, (through E. G. Blackford.) Samples of Alden's vapor-cured snowflake cod-fish, fresh green turtle, and granulated clams.

Aling, D. D. Models of Providence fish-car and snug-stow anchor.

Ames, James T. Box of *Unios*, *Abalones*, &c., polished and unpolished; specimens of emery-stone; box of pearl-oyster shells; emery-ores, and emery with the associated minerals, from Massachusetts.

American Antiquarian Society, Worcester, Mass. Mummy and surroundings, from cave in Kentucky.

American Needle and Fish-Hook Company, New Haven, Conn. Twenty-three cards illustrating the different kinds of hooks made by the company.

American Net and Twine Company, Boston and New York. Samples of eel-pots, lobster-pots, netting-cords, corks, nets, models of fish-traps, mullet cast-net, shrimp, crab, and basket eel-pots manufactured by the company.

Ams, Max., New York. Samples of Hamburger aale, pickled eels, eels rolled and pickled in olives, American pickled eels, and Russian and American caviar.

Agassiz, Alexander. Ores and massive specimens of copper, from the Calumet and Hecla Mine, Michigan.

Army Medical Museum. Moccasins of Santee Sioux, two quivers and two Sioux scalps taken by Chippewa Indians; catlinite pipe, tobacco-pouch, powder-horn and ammunition pouch, and drum-sticks of Yankton Sioux Indians.

Atkins, C. G. Nine models of different kinds of fish-ways in use.

Atwood, Capt. N. E. Samples of fish- and whale-oils, from Massachusetts; samples of sword-fish-, mackerel-, skate-, and halibut-oils, manufactured at Provincetown, Mass.

Bailey, Benjamin S. Black mussel, from Connecticut.

Brackett, E. A. Brackett hatching-box.

Brazil, Commission of, to International Exhibition. Dried air-bladder of pescoda, (fresh-water fish.)

Bailey, S., (through W. H. Dall.) Miscellaneous collections from Washington Territory.

Baird, Prof. S. F. Fresh fish from Philadelphia; box ethnological specimens, from cave at Carlisle, Pa.

Baker, Captain, U. S. Revenue Marine. Eight skins of sea-lion (*Zalophus*), from California.

Baker, Mrs. Marcus. Shells, from Colorado desert.

Baldwin, Mr., (through E. R. Squibb, M. D.) Specimens of chemicals.

Baldwin, D. Box of Indian relics; 3 skeletons of panther (*Felis concolor*), and skull of skunk, from Colorado.

Ballou, W. H. Arrow-heads, from New York.

Banta, George A., New York. Chest refrigerator.

Barber, E. A. Nest of broad-tailed humming-bird (*Selasphorus platycercus*) from Colorado; 2 nests of chipping sparrow (*Spizclla socialis*), and pieces of pottery, from Pennsylvania; collection of pottery, arrow-heads, and beads, from ruins in Utah, Colorado, and Arizona.

Barney, George, Swanton, Vt. Samples of various colors and grades of polished marble in cubic blocks; 2 panels of marble tiling.

Barnum & Richardson Company. Iron-ores and specimens of iron, from Connecticut.

Barroeta, Dr. G. Specimens of silver-ore and plants, from San Luis Potosi, Mexico.

Bartlett, J. H. & Sons. Paddles, harpoon-head, sperm-whale's teeth, &c.

Batchelder, J. H. Paper-folder made of seaweed (*Laminaria longicruris*).

Baxter, J. N., (for Rutland Marble Company, Vermont.) A suite of all grades of marble in large polished slabs and cubes, and photographs of the quarries of the company.

Baxter, Joseph. Hematite iron, from Virginia.

Bean, Tarleton H., M. D. Specimens of sturgeon (*Acipenser oxyrhynchus*), young *Petromyzon americanus* and *Catostomus teres*, from Freestone Point, Potomac River.

Beardslee, Commander L. A., U. S. N. Young sturgeon and flat-fish, from Potomac River.

Beasley, Thomas. Two specimens of horseshoe-crab (*Limulus*), and box of "cancrine."

Beckwith, Paul. Four boxes ethnological specimens, from Devil's Lake agency.

Bell & Mackey, (through Hon. J. P. Woolman.) Collection of silver-ores, from Nevada.

Bendire, Capt. Charles, U. S. A. Alcoholic specimen of waxwing (*Ampelis garrulus*), 22 skins of gray-crowned finches (*Leucosticte*), skins of rodents, grouse, finches, and sparrows.

Bennett, John, (through J. G. Swan.) Collection of native grass and plants, from Washington Territory.

Berdell, Dr. Theodore. Copper- and silver-ores, from Colorado.

Berthoud, Edward L. Collection of ores and minerals, from Colorado.

Bigaglia, P. & Co. Four hundred and seventy-nine patterns of venetian beads. (Purchased.)

Black, S. W. Box of minerals, from Texas.

Blackford, Eugene G. Specimens of pike, fresh fish, oysters, from Massachusetts, and clams from Long Island; clams and mussels from Oyster Bay and Canarsie; loggerhead-turtle (*Thallassochelys caouana*), large bivalves, oysters, white-fish (*Coregonus*), Greenland halibut (*Reinhardtus hippoglossoides*), quinnat salmon and lobster; oysters, from Long Island and coast of Virginia.

Blake, Prof. W. P. Nine boxes of minerals.

Blandy, John F. Collection of minerals.

Blankinship, John. Stone pipe and alcoholic specimens, from Tennessee.

Blatchford, Edwin. Mackerel-rimmer.

Boehmer, George H. Minerals, nest and eggs of pewee, skeleton of mouse, from Maryland.

Boerner, G. C. Grasshoppers, from Indiana.

Botkin, W. A. Crystallized galena, from Missouri.

Bouvé, Thomas T. Specimens of polished porphyry, showing origin of the rocks.

Bowers, Stephen. Seven boxes of ethnological specimens and natural history, from Santa Barbara.

Bowie, Mrs. R. G. Specimen of short tailed shrew (*Blarina brevicauda*).

Boyd, C. R. Ores and minerals.

Bracket, Col. A. G., U. S. A. Weasel, in flesh; badger-skin, skins of *Carpodacus, Pelecanus*, and *Eremophila;* 2 hawks, in flesh; specimen of Washington eagle and Arctic bluebird; 6 specimens of horned lark (*Eremophila alpestris*), in flesh; and specimens of *Leucosticte* and *Junco*, from Wyoming.

Bradford and Anthony, Boston, Mass. Six boxes of fishing-tackle; patent net, staff, and ring; 2 boxes of sportsman's utensils; plated ice-chisel, and reel. (Deposited for Centennial.)

Bradford, I. Rocks from Arkansas.

Bradley, Prof. Frank H. A suite of rock-specimens, from Georgia and the western part of North Carolina.

Bransford, Dr. John F., U. S. N. Ten boxes of ethnologica and general natural history, from Nicaragua.

Brasher, P. Model of Egg Harbor skiff.

Breed, E. E. Two eggs of Carolina dove, Wisconsin.

Breedon, I. Chrysalids from Michigan.

Breedon, Jacob. Collection of beetles, &c., Virginia.

Brewer, James D. Three models of fish-ways.

Briggs, John. Stone implements, from Oregon.
Broadhead, Prof. G. C. Collection of Missouri ores and minerals; geological report and maps.
Brower, J. M. Ethnologica and objects of natural history, from Fiji Islands.
Brown, Dr. J. J. Specimens of *Unio*, &c., from Wisconsin.
Brown, Solomon G. Hare (*Lepus cunicularia*).
Brown, Dr. William H. Shells, from Cedarville, N. Y.
Brown, William H. Samples of glue and isinglass, from Massachusetts.
Brownson & Co. Fossil bone, Texas.
Bryce, Walker & Co. Collection of minerals.
Buck, Jonathan. Two pairs of fisherman's boots, and one of slips.
Budlong, Colonel. Samples of lead-ore, from Missouri.
Buel, Bela S. Gold-ores, from Colorado.
Buel, J. T. Samples of spoon-baits for bass-, pickerel-, pike-, and trout-fishing.
Burchard, ——. Two young living alligators, from Florida.
Burling, William. Box of cinnabar, from California.
Burt, Mrs. Hannah M. Mackerel-rimmer, used 15 years ago.
Burton, A. A. Stone implements, from Illinois.
Burritt, Francis. Four decoy-ducks.
Cambridge, Mass., Museum of Comparative Zoölogy. Alcoholic fishes, from Brazil.
Cannelton Coal Company. Section of coal-bed, with ornamental stand and frame, from West Virginia.
Canfield, C. B., (for the New England Granite Company of Hartford, Conn.) Specimens of Westerly granite and a large polished granite slab.
Cape Ann Isinglass and Glue Company. Specimens of fish-sounds.
Cape of Good Hope, (C. Coates, commissioner.) Fresh-pressed crayfish.
Carley, B. J. M., Fulton Market, New York. Shells of oysters and clams from various places along the coast of the United States.
Carlin, J. S. F., (through J. A. Carlin.) Specimen of horned frog, (*Phrynosoma*,) Northern Pacific Railroad.
Carpenter, Lieut. W. L., U. S. A. Collection of land- and fresh-water-shells, from New Mexico and Arizona; collection of embryonic birds and eggs; box of vertebrate fossils, from Nebraska.
Carter, John F. Samples of oiled clothes used by the fishermen of Cape Ann.
Castine Packing Company, Castine, Me. Fourteen cans and one jar of oysters, clams, lobsters, &c.
Caton, Judge J. D. Skin of black-tailed deer (*Cariacus columbianus var.*) from Santa Barbara.
Central Park Menagerie, W. A. Conklin, director, New York. Sea-dog, (*Zalophus gilliespii*), in flesh.
Chapman, W. D. Chapman's combination trolling-pole, harpoon, and

line-holder; samples of spoon-baits for bass-, pickerel-, pike-, and trout-fishing.

Charles, H. Bird-shaped ethnological object, from Indiana.

Chase, William H. Models of Nantucket fishing-boats and salt-mill.

Chester, Capt. H. C. Models of oyster boat and car, fishing-smack, Block Island boat, and menhaden purse-seine; scrimshawed tusks of walrus.

Chicago Feather-Duster Company, Chicago, Ill. Series of domestic turkey-feather dusters, 5 sizes.

Cincinnati Society of Natural History, (H. Schroyer.) Cast of ox-horn; head of fossil ox; casts of horn-cores of fossil ox.

Clarke, F. L. Specimen of *Gordius*, from Haleakala Mountains, Hawaii.

Clark, F. W. Fish-hatching apparatus.

Clark, George. Model of seine-boat, from Michigan; specimens of *Coregonus albus*, from Lake Michigan.

Clark, J. H. Ethnological and natural-history specimens, from Rhode Island.

Clark & Schneider, Baltimore, Md. Two of Clark & Schneider's guns, breech-loading.

Cleveland, William H. Model of No-Man's Land fishing-boat.

Cleveland Historical Society. Bone arrow-points.

Clinton, E. & Co., Philadelphia, Pa. Samples of brushes made from bristles and hair of American animals.

Clinton, Judge G. W. Fish (*Chirostoma*) in alcohol from Niagara River.

Cardington, C. Specimen of *Phymata rosea*, from Southern Florida.

Coffin, Nat. I. Specimen of *Sclerostoma* found in dog's liver.

Cogswell, ——, superintendent, and Hazzard, president, Mine La Motte, Missouri. Collection of ores from locality.

Coleman, Walter and Sons, Providence, R. I. Box of tackle, blocks, &c., used on small fishing-craft.

Collins Company, Collinsville, Conn. An assortment of mining-picks, for decoration and illustration.

Colt's Manufacturing Company, Hartford, Conn. One gun, rifle, and revolver.

Cooper & Hewitt, Trenton, N. J. Samples of ores and products.

Congdon, H. C., foreman Eureka Consolidated Mine, Nevada. Fifty-six specimens of the ores and other specimens illustrating the mine.

Connecticut Centennial Board of Managers, (by W. P. Blake, secretary.) A collection of 12-inch cubes of polished granite from the chief quarries of the State, presented by the quarry-owners; geological map of the State, enlarged from the map of J. G. Percival.

Consul United States, Levuka. Three boxes of skulls and ethnologica, Society Islands.

Cook, J. W. & V. Dried specimens of stickleback (*Gasterosteus*,) from Oregon.

Cook, W. H. & Co., New Bedford, Mass. Whale-lance, harpoons, and toggle-irons.

Cook, Prof. G. H., State geologist, and Professor Smock, assistant. Series of the clays of New Jersey.

Corliss, Capt. A. W., U. S. A. Five boxes of stone implements, pottery, &c., from Arizona.

Corrigan, J. J. Silver- and gold-ores, from the Eureka mining-district, Nevada.

Corry, J. C., superintendent Ophir Mine, Nevada. Specimens of silver- and gold-ores from the mine.

Craite, Prof. George L. Silver copy of medal in commemoration of birthday of Thomas Carlyle.

Crandall, Charles H. Hammer caught while fishing for tautog; two walrus-tusks.

Crawford, A. W. Box of land and fresh-water shells, and 3 specimens of *Machæra patula*, from California.

Crittenden, A. R., Middletown, Conn. A very large and complete collection of articles relative to the fisheries, models of fishing-boats, &c., and general natural history, from various portions of the New England States.

Cruikshank, A. B. Cruikshank's patent self-acting safety-cleat.

Curtis, Dr. Josiah. Hollow stone cylinder, stone pipe, &c.

Curtis, Melville. Metallurgical series, from the Manhattan Silver Mill, Nevada.

Curtis, Allen A. Series of silver-ores, from the Reese River lodes, Nevada.

Curtis, Samuel T. Silver- and gold-ores, from Nevada.

Dall, W. H. Models of animal-, fish-, and bird-traps, used on Youkon River; alcoholic specimens, from Massachusetts.

Danilson, William H., agent Bannock, Shoshone, and Snake Indians. Ethnologica, Indian Territory.

Dannfelt, C. Juhlin, commissioner from Sweden. Lapland razor, scabbard, handle, and needle-case, made from reindeer-horn.

Darrow Manufacturing Company, Bristol, Conn. Basket, powder-flasks, doll's head, and coil of rope, made from raw-hide.

Davenport, Iowa, Academy of Natural Sciences. Box of *Unios*.

Davis, O. W., jr., Katahdin Iron Works, Maine. Specimens of the ores, fluxes, and iron produced.

Davis, Edward. Mackerel-rimmer.

Davis, Benjamin. Two large quahaugs, from Providence River.

Davis, S. S., and William Day. Fossil bones and leaf-impressions, from Oregon.

Dean, J. N. Minerals, from Georgia.

De Beck, W. D. Box ethnological and geological specimens, from Ohio and Indiana.

Decamp, W. S. Large specimens of iron-ores illustrative of several mines of New Jersey.

Decatur, Stephen. Silver-ore, Colorado.

Degener, R. C. Indian plant and box of antimony-ore, from South America.

Delano, M. A. Suite of ores from the Phœnix Mine, Michigan.

Delano, Mrs. M. A. Large crystalline specimen of copper, from Michigan.

De Long & Sons, Glen's Falls, N. Y. Double-paddle pair of oars, 7 feet 8 inches long.

Derry, C. W. Mammal-skins, from Colorado.

Dickinson, P. Specimens of discoidal stones, from Tennessee.

Dias, Charles H. *Pholas*-eaten rock, from Pacific coast.

Dixon, Robert. Box of Damariscotta oysters.

Dougherty, E. D. Marble in cubes, slabs, and blocks; polished, massive specimen in trophy, showing fossil. From the Dougherty quarries.

Douglas, James, jr. Suite of specimens illustrating the extraction of copper from its ores by the "wet way," Hunt & Douglas process, Phœnixville, Pennsylvania.

Douglas, H. T. & W. G. Box of minerals, from Virginia.

Douglas, Col. John D. Concretion, from Virginia.

Doyer, S. S., agent. Indian curiosities.

Dresser, J. W. Series of fishing-lines in white and oiled linen.

Dulin, R. A. Specimens of quartz-crystals.

Dunan, W. S, Baltimore, Md. Eight cans of fertilizing-material.

Duncklee, H. L., Boston, Mass. Camp stove and furniture.

Eagle Preserved Fish Company, New York. Samples of Krauter anchovies, and Russian sardines.

Edwards, Vinal N. See under *Washington, U. S. Commission Fish and Fisheries.*

Elliott, S. A. Specimen of gold-ore, showing free gold, from Colorado.

Ellis, J. B. One hundred and fifty specimens of fungi, New Jersey.

Elwell, Samuel, jr. Dory thole-pin; row-locks; wooden jib-hank; 2 belaying-pins; porgy slivering-knife; 3 mackerel-rimmers; pair of mackerel-cots, used on the fingers when taking mackerel by hook and line; model of Gloucester fisherman of 1835.

Ely, Smith. A suite of specimens illustrating the copper-ores of the locality and the extraction of copper by smelting; bars of copper, &c.

English, William. Canoe and paddles.

Endlich, Dr. F. M. Mammal-skin, from Kansas.

Emerson, B. F. Specimens of copper and copper-ores, from Michigan.

Eureka Manufacturing Company, Boston, Mass. Bedford air-pistol.

Evans, Capt. William. Fishes in alcohol, from Virginia.

Ewing, Thomas E. Specimens of ores, from Arizona.

Edmunds, Dr. M. C. Lake-trout, from Lake Memphremagog.

Everdeen, J. J. Trawl-buoy.

Fair, James G. Rich and characteristic specimen of the silver-ores of the Comstock lode, Nevada.

Fallin, C. Willis. Specimen of albino Virginia quail (*Ortyx virginianus*), in flesh.

Farlow, Dr. W. G. Sponge-tents, made of dried stems of *Laminaria*, and specimens of *Algæ*.

Farmin, Giles. Stone implements, from Minnesota.

Farwell, O. A., and M. H. Simpson, president Cliff Mine, Boston. Specimens of copper, copper-rock, ancient tools, &c.

Fenner, C. A. Model of extension boat.

Ferguson, Maj. T. B., Maryland Commissioner of Fisheries. Model of oyster-schooner; 4 boxes of oysters; 2 boxes of shells; specimens of *Etheostomoids*, *Cyprinodonts*, and *Cyprinoids*.

Fitzhugh, D. H., jr. Three wooden lure-fishes; model of Au Sable fishing-boat.

Fletcher, Edward H., (through Harper Brothers.) Specimens of minerals from Bergen Hill, New Jersey.

Fletcher, Dr. W. W. White-fish (*Coregonus novangliæ*), from New Hampshire.

Flint, Dr. Earl. Collection of Mexican antiquities.

Foster, J. W. Sail-thimble, made from bone of whale.

Foster, T. G. Soapstone bowl, two axes, arrow-heads, and stone celts, from North Carolina.

Fraser, C. A., (through C. R. Douglas, United States consul, Puerto Plata.) Specimens of wood, &c.

Freeman, Sanford. Mackerel-rimmer.

Friel, Joseph. Box of ethnologica, from Tennessee.

French, E. W. Model of birch-bark canoe, Passamaquoddy Indians.

Gabb, Prof. W. M. Six specimens of stone implements, from West Indies. Copper medal, Colorado.

Gashwiler, General J. W. Silver-ores, Nevada.

Gates, O. Casts of stone implements, from Ohio.

Gavitt, W. E. Box of rocks.

Gesner, William. Ores, minerals, and coal, from Alabama.

Gideon, B. W. Box of ethnologica, from Georgia.

Gifford, J. D. New Jersey sneak-box.

Gilbert, E. F. Specimens of shell- and feather-work; jewelry made from teeth of alligators, and 3 specimens of grasshopper and ichneumon fly.

Gilliss, Capt. Jas., U. S. A. Male panther (*Felis concolor*), in flesh, from Wyoming Territory.

Gloucester Isinglass and Glue Company, William A. Paiz, agent, Boston, Mass. Prepared glue, rough or "court-plaster" glue, and isinglass, made from skin of cod (*Gadus morrhua*).

Goodale, S. L. Extract of fish (menhaden) and oil.

Goode, G. Brown. Specimens of *Acipenser oxyrhynchus*, young, and *Petromyzon americanus;* 4 skins of eel (*Anguilla bostoniensis*); *Coquina*, from Florida; skin of Virginia deer.

Goode, F. C. Four gophers and alligator (*Alligator mississippiensis*), from Florida.

Goldschmidt, S. A. Alcoholic specimen of *Ostracion punctatus*, New York.

Gowen, Franklin, president Reading Railroad Company, Pennsylvania. A complete section of the mammoth vein of anthracite coal, Plank Ridge colliery.

Gordon, W. Alexander. Alcoholic specimens of shrimps and Lake Pontchartrain oysters; specimen of snake (*Tropidonotus fasciatus*), from Louisiana.

Goulding, B. L. Specimens of coral, from Falls of Ohio.

Gower, Frederic A. Sock-joint row-lock.

Graham, T. J. Silver-ores and galenite.

Graves, Frederick D. Patent improved noiseless row-lock.

Green, H. A. Specimens of minerals, from New Jersey.

Green, L. Noank lobster-pot.

Griest, Jesse W., agent. Ethnologica.

Griffin, Dr. Louis P. Specimens of natural history.

Griffin, C. B. Specimens of natural history.

Griffin Brothers. Samples of smoked herrings; keg of Quoddy River herring.

Gruber, F. Specimen of spotted seal (*Phoca richardsii*), 2 skins of black-tailed deer (*Cariacus columbianus*), and skin of sea-lion (*Eumetopias stelleri*), from California.

Gutierrez, M. Julian, manager Tecali Company, Puebla, Mexico. Mexican onyx, travertine limestone, Tecali quarries, (through Professor Barcena, Puebla, Mexico.)

Haggin, James B., president K. K. Consolidated Mine Company. Silver-ores and metallurgical specimens, including bars of unparted bullion.

Hahn, F. L. Silver-ore, galena, and pyrites.

Haigh, A. V. Squirrel-skin, arrow-head, and lower jaw of alligator.

Haines, Hiram, State geologist. A geological map of Alabama.

Hall, J. F. Bottle of "yellow-tails" (*Bairdiella punctata*).

Hall, Prof. James. Cast of lower jaw of Cohoes mastodon.

Hall & Company, Pennsylvania. Cap-extractors, &c., for guns.

Hamilton, A. C., superintendent. Specimens of ores, from the Savage Mine, Nevada.

Hammond, General John F. A series of iron-ores, fuel, fluxes, and products, from Crown Point, N. Y.

Hanchet, L. Large and rich specimen of silver-ores, from Nevada.

Hancock, Hon. Judge. Copper- and zinc-ores, from Texas.

Hardenburgh, A. R. Package of minerals, from California.

Harris, D. W. Oriole's nest and twig of white oak, from Louisiana.

Harris, L. B. Collection of minerals.

Harris, J. S., assistant engineer Reading Coal and Iron Company. A large collection of coal plants and fossils, from the coal-beds of the company.

Harrison, Edwin. Massive specimen of iron-ore, from Iron Mountain, Missouri.

Harvey & Ford, Philadelphia. Carved bone, ivory, and shell articles.

Haven, Williams & Company, Philadelphia, Pa. Seal-skins, from South Sea Islands. Whale-boat and fittings.

Haynes, B. Kaolin, from Florida.

Haywood, Howard. Stone implements of the Oconee-chee Indians.

Hearst, George. Silver-ores, from Nevada.

Heath, Charles G. Pahranagat mining-district ores, Nevada.

Heath, L. J. Specimens of quahaugs (*Cyprina islandica*), whelks (*Fusus islandica*), hen-clam (*Mactra ovalis*), and *Pecten tenuicostatus*, from Maine.

Hedges, S. P. Three eel-spears.

Heinrich, O. J. One box of minerals.

Henning, George C. Lay figure in sportsman's clothes. (Lent.)

Henderson, J. H. Vest made from skin of rattlesnake (*Crotalus durissus*), from Alabama.

Herendeen, Mrs. E. P., (through W. H. Dall.) Stone adze with carved handle, from Fiji Islands.

Herendeen, Capt. E. P., (through W. H. Dall.) Walrus-spear, Walrus Island; bonnet, eye, and baleen of right whale (*Eubalæna cullamach*).

Hering, Dr. C. J. Skins of birds, from Surinam.

Herron, Eli. Model of rabbit-trap.

Higgins & Gifford. Model of Cape Ann seining-boat and dory.

Higgins, Capt. N. Y. Small piece of ambergris from sperm-whale.

Hill, Mrs. D. H., (through Hon. R. B. Vance.) Specimens of malachite and schist, from North Carolina.

Hill, Joel F. Flexible sandstone, from North Carolina.

Hill, A. A. Gold-ores, from Colorado.

Hitchcock, Prof. C. H., Massachusetts. Geological map of the State; a suite of type specimens of the rocks of the White Mountain region; geological and physical maps of the States of Maine, New Hampshire, and Vermont.

Hitchcock, George N. Skin and skeleton of black-tailed deer (*Cariacus macrotis*).

Hobart, Miss M. Stone chisel, from Illinois.

Holabird, W. H. Hunting vest and jacket.

Holmead, William. Snowy owl (*Nyctea nivea*), in flesh, from Mount Pleasant, D. C.

Holst, Professor, Christiania, Norway. Articles made of fish eyes and scales; painted cast of silver nugget.

House, Thomas L. Malformed sucker, Potomac River.

Heran, Thomas. Ethnologica, wood, &c., Medellin, South America.

Horan, Henry. Three models of animal-traps; specimen of *Acipenser oxyrhynchus*, young, *Achirus lineatus*, from Potomac River.

Hoyt Bros. Barrel of oysters.

Hoy, P. R. Broken leaf-shaped implement, from Missouri.

Hunt, A. G. Piece of plank, schooner Carrie Melvin, bored by teredo.

Hurlburt, William I. S. Minerals, from Virginia.

Hussey, Wells & Co., Pittsburgh, Pa. Illustrations of the manufacture of crucible-steel by a series of crucibles, broken to show condition of charge at different heats; specimens of ingots broken and of steel bars of various sizes and grades, all in an ornamental plate-glass case; specimens of flanging, &c.

Hutchinson, John. Package of lance- and arrow-heads, from Illinois.

Hyatt, Prof. A., Boston, Mass. Casts of marine animals.

Ingalls, Frederick. Stone ax, from Illinois.

Isaacs, A. & Co., Boston, Mass. Collection of American and Mediterranean sponges.

Jackson, E. E. Specimens of mud-eel (*Siren lacertina*); and alcoholic fishes, from Columbia, S. C.

Jack, Hon. Edward. Two skins of moose (*Alces malchis*), from Fredericton, N. B.

James, William H. Samples of spoon-baits for bass-, pike-, bluefish-, and trout-fishing.

Japan, Legation of, to the United States. Fur of sea-otter, from Japan.

Jefferey, R. W. Stone implements, from Pennsylvania.

Jencks, Frederick T. Collection of duck- and goose-skins, from Chicago.

Jenks, Prof. J. W. P., and *Newton Dexter.* Specimens of coal and graphite.

Jenks, Col. C. W. Corundum, from North Carolina.

Jewett, Colonel. Crustacean, from mouth of fish, from California.

Jocelyn, Capt. S. P., U. S. A. Gold napkin-ring, made by Haidah Indians. (Loan.)

Johnson, Lyman. Stone ceremonial weapon, from Mississippi.

Johnson & Young, Boston, Mass. Models of lobster-house, schooner, smack "Storm King," two-mast cat-rigged boat "Little Maud;" 7 models of eel-pots, and claw of lobster.

Jones, James. Mineral-ore, from Texas.

Jones, William. Cod-liver oil made from *Pseudophycis breviuscula.*

Joplin, James L., (through W. T. Knott.) Stone pipe, from Kentucky.

Jouy, P. L. Skin of *Sciurus hudsonius.*

Judge, Edwin W. Dog-calls, and fish-trap patented in 1856.

Kallussowski, Dr. Henry. Specimens of giant-beetle (*Dynastes hercules*), and of varied thrush (*Turdus nævius*), from Arkansas.

Keenan, T. J. R. Box of unfinished stone beads, from Mississippi.

Keene, H. B. Specimen gold-ore showing free gold, from Colorado.

Kelsey & Hosmer. Kelsey & Hosmer's fish-dressing machine.

Kemp, Day & Co., New York. Forty cans of lobsters, clams, oysters, &c.

Kempton, C. W. Collection illustrating the argentiferous deposits of Newbury, Mass.

Kennard, Charles W. & Co., Boston, Mass. Tortoise-shell goods.

Keep, M. R. Rudely-chipped implement, from Japan.

Kerr, Prof. W. C., State geologist. Specimens of building-stones, ores, and minerals, from North Carolina.

Keyes, Winfield Scott. Large specimens of lead- and silver-ores, from Nevada.

Kiergaard, F. C. Samples of fish-scale jewelry.

Kingsbury, Frederick J., president Scovill Manufacturing Company, Waterbury, Conn. Samples of copper, zinc, and nickel alloys.

Kinroy, T. W. Copper relics and photographs, from Ohio.

Kirby, H. S. Boat-hooks, pike, &c., used in whale-fishing; eel-spear, and mask, from Friendly Islands.

Knapp, Dr. James. Box of ethnologica, from Kentucky.

Knox, Samuel. Box of shells, from Ohio.

Krider, John. Ten decoy-ducks.

Kumlien, A. L. Specimens of stuffed birds, shells, and mammals, from Texas.

Kusil, F. & Co. Three boxes of minerals, from Utah.

Lamb, Levi. Malformed claw of lobster.

Lapham, Seneca G. Model of animal-mounds of Wisconsin.

Larkin, Prof. E. P. Box of alcoholic fish, and 2 stone sinkers, from Florida.

Latham, J. H. Lantern for eeling.

Latham, B. F. Large lobster-claw, from Connecticut.

Lawler, J. Models of menhaden-steamer and oil-factory, Bristol, Me.

Lechevalier, A. Bird's egg and skins of grebes' breasts.

Ledyard, L. W. Crinoid necklace, from Colorado.

Leete, B. G. Native and table salt, from Nevada.

Lehigh Zinc Works, Bethlehem, Pa. Zinc-ores and products.

Leidy, Joseph, M.D. Part of shell of fossil *Emys*.

Leigh, Sergt. J. A., U. S. A. Twenty-four species of birds and collection of eggs, insects, fossil bones, and fossil teeth, from Nebraska.

LeBaron, J. Francis. Minerals, from Boston.

Leonard, H. L. Three bamboo fishing-rods, (lent,) and 2 pieces of bamboo, showing splitting and gluing. (Presented.)

Lewis, W. K. & Bro., Boston, Mass. Fresh lobster in tin cans.

Lewis, Bull & Co. Silver-ores, galenite, &c.

Lewis, Miss Annie J. Specimen of quahaug (*Cyprina islandica*), from twelve miles off Castine, Me.

Lewis, J. F. Limonite-iron ores, from New York.

Lightner, Joel F., superintendent. Silver-ores, from Nevada.

Lincoln, George F. Combs, jewelry, &c., manufactured from horns and hoofs of cattle.

Lindheimer, F. J. Collection of Indian relics, from Texas.

Liverpool, England, Free Public Museum. Specimen of mullet (*Mullus surmuletus*), and herring, (*Clupea harengus*), from Devonshire coast; mackerel, cod, brill, turbot, 4 specimens of gray mullet (*Mugil*), and specimen of ling (*Lota molva*), pike, and white-bait from Lough Neagh, Ireland.

Lufkin, Charles. Mackerel-jig, style of 1840; petrified wood taken in forty fathoms of water.

Lyman, B. S. Box of Aino articles, from Yokohama, Japan.

Lyman, William. Lyman's patent bow-facing rowing-apparatus.

Mackey, John W. Rich and characteristic specimens of the silver-ores of the Comstock lode, from the Bonanza mines.

Macon, Dr. G. H. Specimen sea-louse (*Squilla*).

Macey, E. B. & F. Collection of whaling-implements, whaling-harpoon, boarding-knife and spade, toggle-iron, &c.

Madison, E. H. Bottle of American "browning," for staining shot-gun and rifle barrels, with pieces of barrels showing manner of staining.

Madison, G. H. Ceremonial stone relic, from Iowa.

Maguire, F. B. Specimens of *Heterostichus rostratus*, *Oxyjulus modestus*, *Syngnathus*, &c.

Mahan, J. L., Indian agent. Specimen of carpet and cloth made by Chippewa women from Odanah Indian Mission, Wisconsin.

Mahrenholz, H. & A., New York. Three pairs of boots made of alligator-, anaconda-, and human skin, respectively.

Mann, John F. Samples of spoon-baits for bass-, pickerel-, pike-, and trout-fishing, nickel-plated.

Manigault, Dr. G. E. Skeleton *Emys serrata*, Charleston, S. C.

Mansfield, G. H. & Co., Canton, Mass. Series of braided silk, cotton, and linen fishing-lines.

Marshall, George. Specimens of opossum (*Didelphys virginianus*), one flying-squirrel (*Sciuropterus volucella*), and birds, from Maryland.

Marvin Brothers & Bartlett, Portsmouth, N. H. Twelve bottles of fish-oils.

Masterson, T. Indian beads, from Pennsylvania.

Massachusetts Arms Company, Chicopee Falls, Mass. Maynard rifle and appurtenances.

Mather, Frederick. Fresh fish and stone beads, from New York.

Mathews & Dugan. Case of horseshoes, showing state of farriery.

Mathews, G. F. Oysters, clams, &c., from Bay of Fundy.

Matteson, F. S. Two myrtle-robins, (*Turdus nævius*), 2 specimens squirrel, (*Sciurus*), 1 specimen showtle (*Haplodontia leporina*).

Maury, Dr. M. F. Sections of the chief coal-beds of West Virginia.

Migler, J. G. & Co., Brookfield, Wash. Ter. Fresh Columbia River salmon in cans.

Merritt, J. C., jr. Three pieces of stone, and specimens of arrow-heads, from New York.

Merry, Henry. Iron-ores, from Lake Superior iron-district.

Miles, George W. Specimens of oil and guano manufactured from menhaden (*Brevoortia menhaden*).

Miller, M. J. Clay bottle; turtle-shaped clay vessel, from Mississippi.

Milner, James W. Models of gill-net and Parmlee's Waukegan fishery; box of bones from mound in Northern Illinois.

Mintzer, Engineer W. A. Birds' eggs; stone lamps and cooking-utensils; Eskimo cranium; marine mollusks; fishes, birds, and antlers; stuffed seal, bows and arrows, mica, &c., from Greenland.

Minnesota Academy of Natural Sciences, P. L. Hatch, corresponding secretary. Cast of human skull, from Palmer's Lake.

Mitchell, J. E. A series of grinding and abrasive stones, oil-stones, whetstones, &c.

Mott, Mrs. C. E. Three boxes feather- and shell-work, made from Florida shells and birds.

Moffat, E. S. A series of the iron-ores of northern New Jersey.

Monfort, Miss M. C. Collection of shells.

Monteith, J. B. Ethnologica.

Moran, Dr. G. H., U. S. A. Red-headed woodpecker (*Melanerpes erythrocephalus*), and collection of reptiles, mice, and moles; nest and eggs; alcoholic specimens of salamanders and snakes, from North Carolina.

Morris, William. Wooden lure-fish for winter-fishing through the ice, and the "otter" to be used in lake and river-fishing.

Moses, John. Samples of pottery and the materials used, from New Jersey.

Mosier, J. L. H. Nodule of flint, with a supposed resemblance to human head.

Moosmueller, Very Rev. Oswald, O. S. B. Fifteen specimens of Indian relics.

Mueller, Dr. Rudolph. Rush mat and arrow-heads made by Chippewa woman, and stone implements, from Carthagena, Ohio.

Murphy, Hon. Patrick. Crystallized masses of lead-ore, melonite, fossil, &c., from Missouri.

McBride, Sara J. Case of salmon-, trout-, and bass-flies.

McChesney, Dr. C. E., U. S. A. Collection of alcoholic mammals; 30 *G. bursarius;* 3 *T. talpoides;* prairie-dogs, mice, and shrews; buffalo "chips."

McCormick, Hon. Richard C. Ores from various parts of Arizona.

McCoy, Maj. W. Wirt. Silver-ores and metallurgical specimens, from Nevada.

McCully, William & Co., Pittsburgh, Pa. Specimens of bottles of different sizes and forms, with materials used in the manufacture of glass.

McCurdy, Alexander. Fisherman's marline-spike; hand-line gear for halibut and cod, used on Saint George's Banks; collection of fishing-implements.

McDonald, Allen L. Trawl-roller used to haul in trawls over the sides of the dory; stay-sail snatch cleat, used by Gloucester fishing-schooners.

McElderry, Dr. Henry, U. S. A. Four dried skins of salmon; Brewer's blackbird, in flesh.

McFadyn, Malcom. Scrimshawed tooth of sperm-whale (*Physeter macrocephalus*), and model of topmast-schooner in use 60 years ago.

McKee, G. P. Alcoholic specimens of herring (*Pomolobus chrysochloris*) from Pearl River, Miss.

McLeod, Rev. R. R. Specimen of sable (*Mustela americana*), 2 specimens of white-haired porcupine (*Erethizon dorsatus*), fisher (*Mustela pennanti*), four hoofs of reindeer (*Tarandus rangifer*), and beaver (*Castor canadensis*), male and female, in flesh, from Maine. (Purchased.)

McMasters, G. M. Specimen gold-ore, showing free gold, from Colorado.

McLaughlin, W. B. Model of herring-weir, from Grand Manan, N. B.

Miles Brothers & Co., New York. Collection of brushes made from the tail-hairs of squirrels, &c.

National Preserving Company, Baltimore, Md. Can of condensed pulverized raw beef.

Neff, Peter. Bottle of diamond lamp-black; tube filled with borings, showing strata.

Nelson, E. W. Skins of water-birds, from Illinois.

Nevada, State Board of Centennial Managers, C. C. Stevenson, chairman. Large collection of silver-ores and other materials of economic importance, presented by authority of the State legislature.

New Jersey Zinc Company, E. S. Baker, president, J. George, superintendent. A massive collection of the ores and minerals of Mine Hill, and of Sterling Hill, Sussex County, with samples of metallurgical products, zinc, and spiegeleisen.

New York Condensed Milk Company, Brewster's, N. Y. Borden's extract of beef, cocoa, milk, &c.

Nichols, J. A. Trunk and bale of fishing-rods and sporting goods. (Lent.)

Niles, Kossuth, Master, U. S. N. Box of oysters from Appalachicola Bay.

Norman, A. J. Three gun-recoil checks.

Olmstead, E. B. Collection of Indian stone implements, from Tennessee.

Oneida Community, Oneida, N. Y. Full series of traps for catching game.

Oregon Packing Company, Portland, Oreg. Box of Cook's Columbia River fresh salmon; spring-salmon bellies, salted.

Page, Kidder and Fletcher, New York. Logs of wood bored by teredo. Petroleum and coal-tar products.

Palmer, Dr. E. Three boxes and one bale ethnologica, from Utah; skin of bat; box of ethnologica, from California; birch-bark canoe, Passamaquoddy Indians, Eastport, Me.

Park, Brothers & Co., Pittsburgh, Pa. Illustration on a large scale of the production and use of cast or crucible steel; specimens of flanging; steel trophy; objects made of crucible steel.

Parker, Charles H. Piece of planking of brig H. B. Emery, bored by the teredo.

Parker, W. F. Pigeon-trap.

Parker, Charles. One Damascus-steel Parker gun.

Parrott, R. D. A., Greenwood Iron Works, New York. Ores, products, &c., and a large display of "slag wool" of all grades.

Passaic Zinc Company, New Jersey, (Manning & Squier, New York.) Zinc-ores, calamine, spelter, &c.

Parsons, Joseph, jr. Pair of nippers, (Gloucester,) and hand-haulers, (Banks of Newfoundland.)

Peabody Museum, Cambridge, Mass. Box of ethnologica.

Peabody, George A. Three bottles of porpoise-oil.

Pennick, N. Shell conglomerate, from Virginia.

Peterson, N. C. Painted shells of mactra.

Phillips, B. Four samples of Spanish nets, machine-made.

Pleasants, General Henry, engineer Reading Coal and Iron Company, Pennsylvania. Series of sections of shafts and coal-beds.

Poole and Hunt, Baltimore, Md. Model of guano-mixer.

Poey, Prof. Felipe. Fish-skeletons; one box minerals, from Cuba.

Ponziglione, Paul M., S. J. Specimen of "prayer-beads-plant" berries (*Sapindus marginatus*).

Potter, Charles T. Model of fish-trap.

Potter, Thomas. Two deformed lobster-claws, from Connecticut.

Potts, John. Specimens of seals, obsidian knives, labrets, figures, &c.

Powell, Maj. J. W. Eleven boxes ethnologica; skull of panther (*Felis concolor*).

Providence Tool Company, Providence, R. I. Peabody-Martini rifle.

Powell, R. H. Birch-bark canoe, from Montagenant Indians.

Powers, Stephen. Specimens of natural history; model of Indian traps; 1 bale and 4 boxes of Indian collections.

Potter, C. V. Clay concretions taken in sixty fathoms of water; coral (*Astrangia danæ.*)

Potter, E. H. Concretion.

Portland Packing Company, Portland, Me. Samples of sugar-corn, Portland blue-berries, champion shell beans, Cumberland roast chicken, Cumberland and potted sausage, Old Orchard Beach clams, fresh star lobster, Cumberland roast turkey, mutton, veal, beef, soup and bouilli, ox-tail soup, fresh Seguin mackerel, fresh star lobster, Yarmouth succotash, in tin cans.

Raht, William L. Models of Indian faces; box stone implements, from Georgia.

Randall, E. H. Box of stone implements and mummied frog.

Rau, Dr. Charles. Cast of bronze sword, found near Braunsberg, Prussia.

Rawlings, Loyd, superintendent, and Thomas Flood, foreman of Silver Hill Mining Company, Nevada. Gold-ores.

Read, Daniel. Selections of colored marbles, polished specimens.

Reeves, S. J., president Phœnix Iron Company, Pennsylvania. Sections of the Phœnix iron columns of all sizes; sections of shape iron; high tower (lent) for support of the column of coal in the Trophy in the center of the Government building.

Republic Iron Company, Michigan. Collection of iron-ores.

Remington, E. & Sons, Ilion, N. Y. One rifle, double barreled breech-loading shot-gun, and one cartridge-loader.

Renfrew, G. R. & Co., Quebec, P. Q. *Beluga* leather and oil, and teeth of *Somniosus.*

Richmond Marble Quarry, Vermont. Large polished and carved block of marble.

Ricksecker, Edmund. Skin, nest, and three eggs of Bewick's wren (*Thryomanes bewickii*), from Texas.

Riddell, J. S. Mineral and ores, from Texas.

Ripley, Sons, J. & Y., Vermont. A suite of all grades of marble, polished slabs and cubes.

Rittenhouse, J. M. Unfinished ceremonial ax, from New Jersey.

Robertson, Rev. W. R. Fossil tooth and bone, from Indian Territory.

Rollins, J. Q. A. Gold-ores, from Colorado.

Roquette, Adrian. Indian basket-work, from Louisiana.

Ross, W. A. & Bro., New York. Samples of English and American cudbear and orchil liquor, and American orchilla weed.

Roth, J. T. Models of fish-way used on Susquehanna River and hatching-apparatus for black bass.

Rowe, Capt. E. L. Two wooden and one soapstone jig-mold.

Russell, John, Cutlery Company, Turner's Falls, Mass. Knives for hunting, sticking, skinning, &c.

Rodgers, Charles. Steatite pipe, from New York.

Rogers, Herbert M. Cod-liver oil.

Salisbury, S. Three oyster-tongs.

Samuels, J. B. Copper-ores, from Virginia.

San Diego, Cal., Academy of Sciences. Stereoscopic views of Indians, and 3 acorns, from Cuyamaca Mountains.

Sautter, Aug. Ground-squirrel, from Illinois.

Sawtelle, H. W., Assistant Surgeon, United States Army. Old flint-gunlock, found near Norfolk, Va.

Schaffer, David H. Specimens of the shells of and jewelry made from the *Unio.*

Scheffer, E. Samples of pure, dry, saccharated, and liquid pepsin.

Schieffelen, H. H. Irish moss, isinglass, and cuttle-fish (*Os sepia*).

Schumacher, Paul. Eight boxes of ethnologica, from Oregon, and 7 boxes from California.

Scott, R. A. Models of Colvin's portable canvas boat.

Scoville & Johnson, Marquette, Mich. Lehnen's patent folding camp-baker.

Shaler, N. S., State geologist, Kentucky. A series of specimens of the ores and coals of the State.

Sharps Rifle Company, Connecticut. Sharps rifle and case.

Shaw, John, Eureka Consolidated Mine, Nevada. Molybdate of lead, and wulfenite.

Shears, D. Clifton. Photograph of moose-horns.

Shepard, Edward M. Ores of Dutchess County, New York. Also, spear- and arrow-heads, from New York.

Shepard, Prof. C. U., jr. Full series illustrating the nature of the fossil-phosphates of South Carolina, utilized for the manufacture of fertilizers, with a map, sections, analyses, &c.

Sherman, D., United States Indian agent. Three boxes of stone and stone implements from Indian graves, from New York.

Skinner, D. M. Series of fluted trolling-spoons.

Slagle, J. W. Two boxes of ethnologica, from Virginia.

Small, E. E. Two bottles of blubber and fifteen of fish- and whale-oils.

Smith, Charles H. Indian samp-stone, from Massachusetts.

Smith, Prof. J. Alden. Gold-ores, from Colorado.

Smith, William H., and H. Donnelly, foreman Belcher Mine. Specimens of the ores of the mine and across the lode.

Smith, N. C. Model of lobster-pot.

Smith, Rev. C. D. Corundum and other minerals, from the western part of the State of North Carolina.

Sociedad Mexicana de Historia Natural, Vera Cruz, Mexico. Box of shells.

Sopries, A. P. Silver-ores, from Colorado.

Soto, O. and M., Santiago, Chili. Mounted specimens of deer, (*Cervus huamel*), condor, and puma.

Southwick, J. M. K. Models of fishing-smack, fisherman's car, and fish-marketman's car; collection of fishing-implements; scoop-net bow used in dipping fish from smack's well.

Squibb, Edward R., M. D. Four bottles of Honduras silver cochineal; castoreum of North American castor; murexide and prophylamine; sea-tangle (*Laminaria digitata*); red and yellow prussiates of potassa.

Sterling, E., M. D. Cast of arrow-straightener, from Ohio.

Sternberg, C. H., M. D., U. S. A. Fossil shells, from Kansas.

Stevenson, James. Oyster-fish, from the Potomac River.

Stockbridge & Co., Gloucester, Mass. Prepared cod-fish.

Stone & Hooper, Charlestown, Vt. Models of tank, rearing-box, carrying-can, and parlor-brook for fish-culture.

Stone, Miss Anabel. "Lobster man."

Stone, Livingston. (See under *Washington, United States Commission of Fish and Fisheries.*) Collection of fishes, &c., from California; 5 models of boats used by the Chinese, Italian, and American fishermen in San Francisco Bay.

Strater, Herman & Sons, Boston, Mass. Tin decoys of ducks, plover, snipe, &c.

Stratton, Capt. Thomas, (through James G. Swan.) Silver and gold articles; also collections of *Mollusca* and *Algæ* from Washington Territory.

Streets, Dr. T. H., U. S. N. Two specimens of *C. virginicus*, and fish.

Streng, L. H. Ninety-five species of fresh-water shells, from Michigan.

Strouse, Henry St. G. Arrow-heads and chippings.

Sutherland, John. Fresh fish (*Coregonus neohantonensis*); 4 specimens cisco (*Argyrosoma clupeiformis*) from Lake Erie; also lake-trout, 2 cusk, and 2 white-fish.

Sutherland Marble Company, Vermont. Polished blocks and masses, monuments, &c.

Tatham & Brother, Pennsylvania. Illustrations of the chief commercial forms of lead; sheet, pipe, shot, &c., &c.; trophy of tin pipe and of tin lined iron pipe.

Thompson, J. H. Specimens of fish, and 2 scales of *Megalops thrissoides.*

Thompson, C. O. Box of minerals.

Thornton, L. B. Box of fresh-water shells, from Alabama.

Throckmorton, S. R. Two fishes, in alcohol, from California.

Treadwell, George C. & Co., Albany, N. Y. Eight seal-skins. (Lent.)

Turner, Lucien M. Ethnological and natural-history specimens, from Alaska.

Turrell, Oscar. Polished chisel of granite; stemmed spear-point, from India.

Underwood, William & Son, Boston, Mass. Samples of canned meats.

Valentine, Mann S. Samples of Valentine's extract of beef; collection of geological specimens, from Virginia.

Vance, Hon. R. B. Chalcopyrite and malachite, from Old Savannah Mine, North Carolina; specimen of tea, from North Carolina.

Van Patten, Dr. Specimen of natural history, from Costa Rica.

Velie, J. W. Conch-harpoon and turtle-peg.

Vickers, General, (through N. M. McDowell.) Two specimens of tinamous (*Nathura perdicaria*), male and female, from Chili.

Voss, A. Mill for cutting fish for bait.

Wallace, John. Water-buffalo (*Bos bubulus*), in flesh; specimen of dolphin (*Delphinus*), and skin of bear (*Ursus montanus*), from Minnesota.

Ward, S. Alcoholic specimens of white-fish (*Coregonus albus*).

Washburn & Möen Company, Worcester, Mass. Iron wire of various sizes.

Wasson, John, surveyor-general of Arizona. Specimens of silver-, lead-, and gold-ores, from various mines in the Territory.

Webb, J. G. Box of ethnologica, from Florida.

Webber, Mrs. F. W. Specimens of fossil corals, also stone pipe, from Alabama.

Welch, Dr. L. B. Casts of grooved and perforate implements.

Welpley, D. P. White rabbit (*Lepus americanus*), from Virginia.

Wells, W. H., M. D. Indian basket of Digger Indians; package of California raisins.

Welsher, H. W. Two bottles of fishes.

Wernigk, Dr. E. Box of minerals, from Illinois.

Wernich and Wander. Two pieces of sturgeon-leather.

Westerberger, Frank. Bone seam-rubber used by sail-makers, made from jaw-bone of sperm-whale (*Physeter macrocephalus*).

Weston, William H. Tin "bung-bucket" or "water-thief," and Provincetown doryman's "fog" or "lipper" horn.

Wetherby, A. G. Fifty species of shells, from Utah.

Wharton, Joseph. Nickel and cobalt ores, massive and selected; associate minerals, and the products; nickel plates, bars, rods, wire, and manufactures, nickel salts, &c.; cobalt in bars; cobalt oxide and salts; nickel magnetic needle; nickel magnet.

Wheatley, Charles M. Suite of specimens illustrating the extraction of copper from its ores by smelting.

Wheaton, W. W. Iron-ores and furnace-products.

Wheeler, S. I. Tuber of tuckahoe, from North Carolina.

White Manufacturing Company. Collection of hunting-lamps.

White, Dr. John B. Ethnological specimens, from California and Arizona.

Whitehill, Dr. H. R., mineralogist of Nevada. Contributions from his private cabinet.

Whitmore, John J., (through C. G. Atkins.) Dried specimen of menhaden (*Brevoortia menhaden*), from mouth of Penobscot River.

Wickes, George F. Ores and minerals, from Virginia.

Wiggins, John B. Minerals, from Virginia.

Wiggins, Pierce. Indian mortar and pestle, from California.

Wiggins, Mrs. Lucinda. Two Indian baskets, from California.

Wilbur, James H., Indian agent. Box of ethnologica, from Washington Territory.

Wilcox, Dr. F. E., U. S. A. Specimen of paludal shells, from Kansas.

Wilcox, Crittenden & Co., Middletown, Conn. Four boxes of boat-fitting apparatus, and apparatus illustrative of the fisheries.

Wilcox Tanning Company, Wilcox, Pa. Tanned skins of bison.

Wilder, General J. T., Tennessee. The ores, coals, fluxes, and other economical minerals of the State and of the Chattanooga iron-district; map of the Chattanooga iron-district, &c.; face carved from shell; pierced and grooved stone sinker; chipped flint flake; large flat (smoothing) tool; stone axes; pestle; spade-like implements; perforated stone (sinker); agricultural implements; two clay bowls.

Wilkins, W. & Co. Series of manufactured bristles and horse hair.

Williamson, George, United States minister. Ancient pottery, from Guatemala.

Willison, J. F. Birds' nests and eggs, from New York.

Winchester Repeating Arms Company, New Haven, Conn. Two rifles and card of cartridges.

Winters, Theodore, Nevada. Specimens bullion from the "Mexican claim."

Witherbee, T. F. Collection of the iron-ores of Essex County, New York, in large and small masses.

Wood, William J., Connecticut, vice-president of the Collins Company, and for the company. A series of specimens illustrating the production and uses of blister-steel in the manufacture of axes, mining-picks, &c.

Woodman, H. T. Collection of stone implements, from Iowa.

Wolcott, Maj. Frank. Two specimens of fishes (alcoholic) from Wyoming Territory.

Woolman, Hon. J. P., Montana. Collections of ores and minerals from various mining-districts contributed by the owners of claims and mines.

Wooster, A. F. Ethnological specimens, from Connecticut.

Wyeth and Brother. Samples of prussiate of potassa, pancreatin, saccharated pepsin, cod-liver oil, and inodorous glycerine.

Washington, D. C.:

Department of State. See under *Isaac Browers, Fiji Islands, George Williamson, United States minister to Guatemala.*

Treasury Department. See under *United States Coast Survey* and *Captain Baker, U. S. Revenue Marine.*

War Department :

United States Army. See under *Col. A. G. Brackett, Captains Charles Bendire, A. W. Corliss, S. P. Jocelyn, Lieutenant W. L. Carpenter, Sergt. J. A. Leigh.*

Quartermaster's Department. Indian dress, from Kansas. See, also, under name of *Capt. James Gilliss.*

Surgeon-General's Office, United States Army Medical Museum. Sixty-four specimens of gold, silver, and copper ores, 4 stone hatchets, two Apache earthen pots, also geological specimens and fossil shells, from New Mexico. See also under the names of *Drs. C. E. McChesney, Henry McElderry, George H. Moran, H. W. Sawtelle, F. E. Wilcox, C. H. Sternberg.*

Surveys west of the one hundredth meridian, Lieut. G. M. Wheeler in charge. Collection of butterflies; *Arachnida;* two boxes of *Coleoptera;* crania of lynx and alcoholic and skin collection of mammals and reptiles; skull of Baird's dolphin (*Delphinus bairdii*); alcoholic collection of spiders and fishes; collection of botanical specimens (*Leguminosa*); 4 mammal-skins, 46 bird's eggs, and 3 lots pinned insects.

Navy Department:

See under *Commander L. A. Beardslee, Master Kossuth Niles.*

Medical Bureau. See under names of *Drs. Palmer, John F. Bransford,* and *Thomas H. Streets.*

Interior Department:

General Land-Office. See under *Surveyors-General A. R. Hardenburgh* and *John Wasson.*

Office Indian Affairs. See under the names of Indian agents *Paul Beckwith, W. H. Danilson, S. S. Dyer, Jesse W. Griest, J. L. Mahan, D. Sherman, J. H. Wilbur;* also under the names of *John Blankinship, S. G. Lapham, E. Palmer, J. W. Powell,* (part,) *Stephen Powers, P. Schumacher,* and *L. M. Turner.*

Survey of the Colorado, (Maj. J. W. Powell in charge.) Eleven boxes ethnologica; skull of panther (*Felis concolor*).

Department of Agriculture, (Hon. Frederick Watts, Commissioner.) Articles of food, medicine, narcotics, vegetable fibers, &c., &c.; bow made of horn of Rocky Mountain sheep; arrows and moccasins, from Rochester Museum.

United States Commission of Fish and Fisheries, (Prof. Spencer F. Baird, Commissioner.) Large collection of fishes and other marine products, models of nets, boats, &c. See, also, under the names of *Charles G. Atkins, T. H. Bean, H. C. Chester, A. L. Kumlien,* and *H. W. Welsher.*

For a separate statement in general terms of the donations of objects of geology, mineralogy, metallurgy, zoölogy, botany, ethnology, and industries of various kinds made by the foreign centennial commissions to the United States, and taken charge of by the Smithsonian Institution, see another part of this Report.

A complete list of the additions to the collection to illustrate the mineral resources of the United States will be given hereafter.

Table showing the number of entries in the record-books of the United States National Museum at the close of the years 1875 and 1876, respectively.

Class.	1875.	1876.
Mammals	12, 462	12, 612
Birds	70, 378	70, 987
Reptiles and amphibians	8, 410	8, 572
Fishes	16, 649	16, 893
Skeletons and skulls	15, 363	15, 442
Eggs	17, 249	17, 301
Crustaceans	2, 210	2, 310
Annelids	100	100
Mollusks	26, 757	30, 721
Radiates	3, 148	3, 229
Invertebrate fossils	7, 905	7, 905
Minerals	9, 394	20, 050
Ethnological specimens	20, 302	27, 880
Total	*210, 327	234, 002
Increase for 1876	....	23, 675

* The corresponding entries for 1875 were 12,578; for 1874, 10,334.

Approximate table of the distribution of duplicate specimens to the end of 1876.

Class.	Distribution to the end of 1874.		Distribution during 1875 and 1876.		Total to the end of 1876.	
	Species.	Specimens.	Species.	Specimens.	Species.	Specimens.
Skeletons and skulls	429	1, 230	102	394	531	1, 624
Mammals	2, 129	4, 779	12	13	2, 141	4, 792
Birds	24, 879	38, 207	937	1, 219	25, 816	39, 426
Reptiles	1, 991	3, 262	14	20	2, 005	3, 282
Fishes	2, 771	5, 815	213	407	2, 984	6, 222
Nests and eggs of birds	7, 172	17, 870	256	258	7, 428	18, 128
Insects	3, 648	8, 294	433	1, 066	4, 081	9, 360
Crustaceans	1, 078	2, 650	....	....	1, 078	2, 650
Shells	89, 789	195, 292	172	222	89, 961	195, 514
Radiates	583	778	....	....	583	778
Other marine invertebrates	1, 844	5, 160	....	....	1, 844	5, 160
Plants and packages of seeds	28, 370	49, 705	80	150	28, 450	49, 855
Fossils	4, 125	10, 154	....	....	4, 125	10, 154
Minerals and rocks	8, 867	16, 252	216	572	9, 083	16, 824
Ethnological specimens	1, 950	2, 069	115	412	2, 065	2, 481
Diatomaceous earths, (packages)	258	1, 012	150	150	408	1, 162
Total	179, 883	362, 529	2, 700	4, 883	182, 583	367, 412

STATISTICS OF LITERARY AND SCIENTIFIC EXCHANGES IN 1876.

BOXES SENT ABROAD.

Agent and country.	No. of boxes.	Cubic feet.
Royal Swedish Academy of Sciences, Stockholm	6	42
Royal Danish Society of Sciences, Copenhagen	5	35
Royal University of Norway, Christiania	3	21
L. Watkins & Co., St. Petersburg, Russia	13	91
Fr. Müller, Amsterdam, for Belgium	6	42
Prof. von Baumhauer, Bureau Scientifique Néerlandais, Harlem	6	42
Dr. Felix Flügel, Leipsic, Germany, Austria, Switzerland, and Greece	56	392
Gustave Bossange, Paris	23	161
U. Hoepli, Reale Istituto Lombardo di Scienze e Lettere, Milano	11	77
William Wesley, London, Great Britain, British possessions in Asia, &c	52	364
Academia Real das Sciencias, Lisbon	3	71
Real Academia de Ciencias, Madrid	1	7
Cuba, Real Universidad de la Habana	1	7
Chili, Universidad	2	14
Mexico, Sociedad Mexicana de Geografia y Estadistica	2	14
Buenos Ayres, Prof. H. Burmeister	1	7
Instituto Historico, Geographico e Ethnografico, Brazil	2	14
Universidad of Costa Rica, San José	1	7
Museum, Sydney	1	7
Public Library, Victoria	6	42
Royal Economical Society of the Philippine Islands, Manila	2	14
Smithsonian system	203	1,421
To foreign governments	120	840
Total, (weight, 80,750 pounds)	323	2,261

NOTE.—12,219 miscellaneous packages, of which 30 contained specimens of natural history, exclusive of 290 Smithsonian Reports of 1875; 160 copies of vol. xx and 160 of vol. xxi of Smithsonian Contributions to Knowledge; in all, 12,829 addressed packages.

International exchange of United States Government's publications in 1876.

	No. of boxes.
Queensland, government of, (per A. Mackey, commissioner, Centennial)	7 A—G.
Victoria, government of Melbourne	7 A—G.
Adelaide, government of South Australia	7 A—G.
Wellington, government of New Zealand, parliamentary library	7 A—G.
Sydney, government of New South Wales	7 A—G.
Hobarton, government of Tasmania, parliamentary library	7 A—G.
Switzerland, (per Swiss consul)	7 A—G.
Sweden, per consulate of Sweden and Norway	7 A—G.
Royal Society, Edinburgh	7 A—G.
Government of Buenos Ayres, (per E. Oldendorff, Centennial Commissioner)	7 A—G.
Government of Hayti, per legation	6 A—F.
Government of Venezuela, (Messrs. Dallett, Bliss & Co., New York)	6 A—F.
Norway, Kongelige Norske Frederiks University, (per Messrs. Wesenberg & Co., Philadelphia)	5 C—G.
Prussia, Royal Library, (per Dr. F. Flügel, Leipsic)	5 C—G.
Germany, Reichstag Bibliothek, Berlin, (per Dr. F. Flügel, Leipsic)	3 E—G.
Saxony, government of, Dresden, (per Dr. F. Flügel, Leipsic)	5 C—G.
British Museum, London	5 C—G.

	No. of boxes.
Spain, government of, (per Centennial Commissioner)	5 C—G.
Turkey, government of, (per légation impériale ottoman)	1 G.
Holland, government of, (per consul-general, New York)	1 G
Belgium, M. le Ministre des Affaires Etrangères	1 G.
Portugal, government of, (per consul-general, New York)	1 G.
Ottawa, parliamentary library	1 G.
Toronto, government of Ontario	1 G.
Mexico, government, (per Juan N. Navarro, New York)	1 G.
Brazil, consulate at Baltimore	I G.
Chili, Muñoz & Espriella, New York	1 G.
Japan, (per legation in Washington)	1 G.
Total	120

N. B.—The boxes are marked A, B, C, D, E, F, G.

PACKAGES RECEIVED BY THE SMITHSONIAN INSTITUTION FROM EUROPE, ETC., IN 1876, FOR DISTRIBUTION IN AMERICA.

ALABAMA.	No.
Tuscaloosa:	
Alabama Insane Hospital	1
ARKANSAS.	
Little Rock:	
Governor of the State of Arkansas	2
State Library	11
CALIFORNIA.	
Oakland:	
Health Office	2
University of California	1
San Francisco:	
Board of Health	2
California Academy of Sciences	70
Geological Survey of California	4
Mayor of the City of San Francisco	1
Stockton:	
Insane Asylum	1
COLORADO.	
Golden City:	
School of Mines	1
CONNECTICUT.	
Hartford:	
State Agricultural Society	1
Young Men's Institute	1
New Haven:	
American Journal of Arts and Sciences	70
American Oriental Society	19
Connecticut Academy of Arts and Sciences	94
Sheffield Scientific School	1
Yale College	25
Middletown:	
Connecticut State Hospital for the Insane	1
DISTRICT OF COLUMBIA.	
Georgetown:	
Georgetown College	5
Washington:	
American Medical Association	3
Bureau of Education	5
Bureau of Navigation	10
Bureau of Ordnance	4
Bureau of Statistics	8
Census Bureau	5
Coast-Survey Office	57
Columbian University	3
Columbia Institution for the Deaf and Dumb	1
Department of Agriculture	124
Engineer Department	11
General Land-Office	5
Interior Department	2
Library of Congress	20
Light-House Board	1
Medical Society of the District of Columbia	1
National Academy of Sciences	70
National Deaf-Mute College	1
Nautical Almanac Office	4
Navy Department	3
President of the United States	1
Signal-Office	36
Surgeon-General's Office	111
Swedish and Norwegian Legation	1
Treasury Department	3
United States Commission for Fisheries	3
United States Geological Survey of the Territories	69
United States Naval Observatory	57
United States Patent-Office	128
War Department	3
GEORGIA.	
Athens:	
State Agricultural College	1
Savannah:	
Historical Society of Georgia	2

Packages received by the Smithsonian Institution, &c.—Continued.

ILLINOIS.

Chicago:	
Chicago Academy of Science	53
Chicago Public Library	5
Dearborn Observatory	4
Mayor of the City of Chicago	1
Elgin:	
Northern Illinois Hospital	1
Jacksonville:	
Illinois State Hospital	1
Ottawa:	
Academy of Natural Sciences	2
Rantoul:	
Rantoul Literary Society	1
Springfield:	
Academy of Science	1

INDIANA.

Indianapolis:	
Geological Survey of Indiana	5
Horticultural Society of Indiana	1
Indiana Institution for the Blind	1
Indiana Institution for the Deaf and Dumb	1
Lafayette:	
Pardue University	1

IOWA.

Davenport:	
Academy of Natural Sciences	4
Des Moines:	
State Library	4
Iowa City:	
Iowa State University	24

KENTUCKY.

Frankfort:	
Geological Survey of Kentucky	3
State Library	1
Louisville:	
Mayor of the city of Louisville	1

LOUISIANA.

New Orleans:	
New Orleans Academy of Science	33
State Library	9

MAINE.

Augusta:	
Maine Board of Agriculture	1
State Library	1
Brunswick:	
Bowdoin College	4
Maine Historical Society	3
Portland:	
Portland Society of Natural History	46
Waterville:	
Colby University	1

MARYLAND.

Annapolis:	
United States Naval Academy	1
Baltimore:	
Johns Hopkins University	6
Maryland Academy of Sciences	2
Maryland Historical Society	2
Peabody Institute	2

MASSACHUSETTS.

Amherst:	
Amherst College	3
Boston:	
American Academy of Arts and Sciences	146
American Social Science Association	2
American Statistical Association	8
Board of Education	1
Board of State Charities	3
Boston Art Club	2
Boston Athenæum	2
Boston Hospital	1
Boston Medical and Surgical Journal	10
Boston Natural History Society	201
Bowditch Library	1
Gyncæological Society	1
Massachusetts Historical Society	1
Mayor of the city of Boston	1
New England Genealogic Historical Society	1
Ornithological Club	1
Perkins Institution for the Blind	1
Public Library	17
Sanitary Commission	1
State Board of Agriculture	2
State Board of Health	1
State Library	8
Cambridge:	
Harvard College	35
Harvard College Herbarium	1
Harvard College Observatory	27
Museum of Comparative Zoölogy	85
Peabody Museum of American Archæology and Ethnology	3
Jamaica Plain:	
Bussey Institution	7
Northampton:	
Clarke Institution for the Deaf and Dumb	1
State Hospital for the Insane	1
Salem:	
American Association for the Advancement of Science	45
American Naturalist	12
Essex Institute	92
Peabody Academy of Sciences	85
Somerville:	
McLean Asylum for the Insane	1
Worcester:	
American Antiquarian Society	11
Institute of Technology	3

Packages received by the Smithsonian Institution, &c.—Continued.

MICHIGAN.

Ann Arbor:	
Observatory	9
University of Michigan	2
Detroit:	
Michigan State Agricultural Society	8
Review of Medicine and Pharmacy	9
Lansing:	
Geological Survey of Michigan	16
Michigan State Board of Health	1

MINNESOTA.

Minneapolis:	
Minnesota Academy of Sciences	7
Saint Anthony:	
University of Minnesota	2
Saint Paul:	
Minnesota Historical Society	5
Saint Peter:	
Minnesota State Hospital for Insane	1

MISSOURI.

Saint Louis:	
Geological Survey of Missouri	13
Governor of the State of Missouri	1
Saint Louis Academy of Sciences	110
State Board of Agriculture	4
University of Saint Louis	2
Washington University	1

NEW HAMPSHIRE.

Concord:	
Dartmouth College	3
Dartmouth College Observatory	1
New Hampshire Asylum for Insane	1
New Hampshire Historical Society	2

NEW JERSEY.

Hoboken:	
Stevens Institute of Technology	11
New Brunswick:	
Geological Survey of New Jersey	6
Princeton:	
College of New Jersey	5

NEW YORK.

Albany:	
Albany Institute	21
Dudley Observatory	22
New York State Agricultural Society	22
New York State Library	47
New York State Medical Society	1
New York State Museum of Natural History	10
New York State University	8
Blackwell's Island:	
New York City Lunatic Asylum	1

NEW YORK—Continued.

Brooklyn:	
Long Island Historical Society	1
Mercantile Library Association	1
Buffalo:	
Buffalo Society of Natural Sciences	47
Canandaigua:	
Brigham Hall Hospital	1
Clinton:	
Hamilton College	1
Litchfield Observatory of Hamilton College	4
Hudson:	
Observatory	1
Ithaca:	
Cornell University	6
Le Roy:	
Ingham University	1
Lima:	
Genesee College	1
New York:	
American Chemist	3
American Geographical Society	59
American Institute	20
American Institute of Architects	17
American Museum of Natural History	20
American Public Health Association	1
American Society of Civil Engineers	11
Anthropological Institute of New York	17
Astor Library	13
Board of Commissioners of Central Park	1
Board of Health	1
Columbia College	1
Cooper Union	2
Engineering and Mining Journal	11
General Society of Mechanics and Tradesmen	1
Insurance Department	1
International Review	1
Lenox Library	3
Manufacturer and Builder	13
Mayor of the city of New York	1
Mechanics' Institute	1
Mercantile Library Association	2
Merchants and Clerks' Library Association	1
Meteorological Observatory	8
Metropolitan Museum of Art	2
New York Academy of Medicine	3
New York Academy of Sciences	87
New York Historical Society	5
New York Tribune	1
Sanitarian	10
School of Mines	8
União Scientifico Brazileira	1
United States Sanitary Commission	5
University of the city of New York	4
Poughkeepsie:	
Public Library	1
Vassar College	1

Packages received by the Smithsonian Institution, &c.—Continued.

NEW YORK—Continued.

Rhinebeck:
Saint Joseph's College 1
Rochester:
University of Rochester 1
Schenectady:
Union College 1
Syracuse:
Public Library 1
Syracuse University 1
Troy:
Rensselaer Polytechnic Institute 2
Utica:
State Lunatic Asylum 1
Willard:
Willard Asylum for the Insane 1

NORTH CAROLINA.

Chapel Hill:
University of North Carolina 1

OHIO.

Cincinnati:
Astronomical Observatory 15
Cincinnati Quarterly Journal of Science 1
Longview Asylum 1
Mayor of the City of Cincinnati 1
Mercantile Library 1
Ohio State Board of Agriculture 52
Public Library 3
Columbus:
Geological Survey of Ohio 8
State Library 11
Gambier:
Kenyon College 1
North Bend:
Horticultural Society of Ohio 4
Oberlin:
Oberlin College 1

OREGON.

Salem:
Willamette Observatory 1

PENNSYLVANIA.

Alleghany:
Alleghany Observatory 10
Danville:
State Hospital for the Insane 1
Easton:
American Institute of Mining Engineers 7
Lafayette College 1
Harrisburgh:
Geological Survey of Pennsylvania 2
Pennsylvania State Agricultural Society 1
State Library 2
State Lunatic Hospital 1

PENNSYLVANIA—Continued.

Philadelphia:
Academy of Natural Sciences 175
American Entomological Society 20
American Journal of Conchology 4
American Pharmaceutical Association 23
American Philosophical Society 107
Asylum for the Insane 1
Board of Education 3
Board of Health 2
Central High School 1
Franklin Institute 30
Historical Society of Pennsylvania 3
Library Company 1
Medical Times 11
Mayor of the City of Philadelphia 1
Medical Society of Pennsylvania 1
Numismatic and Antiquarian Society 1
Observatory 8
Pennsylvania Hospital 1
Pennsylvania Institution for the Deaf and Dumb 1
Penn Monthly 1
Pennsylvania Society for the Prevention of Cruelty to Animals 1
Polytechnic Review 1
Social Science Association 1
Wagner Free Institute of Science 12
Zoölogical Society 5
South Bethlehem:
Lehigh University 1

RHODE ISLAND.

Providence:
Brown University 2
Butler Hospital for the Insane 1
City Registrar's Office 1

SOUTH CAROLINA.

Charleston:
Charleston Library Society 1
Elliott Society of Natural History 14
South Carolina Medical Association 1
Columbia:
University of South Carolina 1

TENNESSEE.

Nashville:
State Library 2

TEXAS.

Chapel Hill:
Soulé University 5

VERMONT.

Derby:
Orleans Society of Natural Science 36
Burlington:
University of Vermont 2
Montpelier:
State Library 2

Packages received by the Smithsonian Institution, &c.—Continued.

VIRGINIA.

Charlottesville:	
University of Virginia	3
Hampton:	
Hampton Normal Institute	2
Lexington:	
Washington and Lee University	1
New Market:	
Polytechnic Institute	2
Richmond:	
Medical Society of Virginia	1
Southern Fertilizing Company	1
State Library	1
Williamsburgh:	
Eastern Lunatic Asylum	1

WISCONSIN.

Janesville:	
Wisconsin Institute for the Blind	1
Madison:	
College of Arts	1
Wisconsin Academy of Sciences, Arts, and Letters	47
Wisconsin State Agricultural Society	25
State Historical Society of Wisconsin	7
Madison University	1
Milwaukee:	
Natural History Society	1
Neenah:	
Scandinavian Library Association	1

BRITISH AMERICA.

Charlottetown, Prince Edward Island:	
Colonial Library	2
Fredericton, New Brunswick:	
Legislative Library	2
University of New Brunswick	2
Halifax, Nova Scotia:	
Board of Agriculture	1
Dalhousie College	1
Kingston, Ontario:	
Botanical Society of Canada	1
Montreal, Quebec:	
Board of Agriculture	1
Geological Survey of Canada	16
McGill College	1
Montreal Historical Society	2
Natural History Society	29
Royal Canadian United Service Institution	1
Société d'Agriculture du Bas-Canada	1
Ottawa, Ontario:	
Library of Parliament	2
Quebec, Quebec:	
Laval University	2
Le Naturaliste Canadien	1
Literary and Historical Society	8
Observatory	5

BRITISH AMERICA—Continued.

St. John's, New Brunswick:	
Mechanics' Institute	2
Toronto, Ontario:	
Canadian Institute	16
Magnetic and Meteorological Observatory	13
Meteorological office	1
Provincial Meteorological Observatory	3
Trinity College Library	2
University of Toronto	4

INDIVIDUALS.

Abbe, Prof. C	9
Agassiz, Prof. A	12
Agassiz, Mrs. E	1
Allen, Prof. J. A	1
Alvord, Brevet Brigadier-General	1
Anderson, Prof. R. B	1
Angerer, A. W	4
Anthony, J. G	1
Ashley, A	1
Bagley, Governor J. J	1
Baird, Prof. S. F	43
Ballard, J	1
Bancroft, Hon. G	6
Bancroft, H	1
Bandelin, Mr	1
Barbank, Professor	1
Barcena, Prof. M	6
Barker, Prof. G. F	2
Barnard, Dr	1
Baxter, Hon. W. J	1
Beadle, E. R	1
Bean, T. H	1
Bell, Dr. R	4
Bennet, J. G	1
Berckmans, Professor	1
Bessels, Dr. E	11
Bessey, Prof. C. E	1
Billings, Dr. J. S	1
Blake, J. H	1
Blake, Prof. W. P	4
Bland, T	1
Blandy, J. F	1
Bliss, R	1
Blodget, L	1
Boardman, S. L	1
Boehmer, G. H	2
Bowers, Rev. S	1
Brabrook, S. G	1
Brannan, L. A. L	1
Brendel, Dr. F	4
Brewer, Dr. T. M	9
Brigham, Dr. C. B	1
Broadhead, G. C	3
Brooks, C. W	1
Brooks, T. B	1
Brooks, W. K	1
Brown, J. C	2
Brown, S	2
Brush, Prof. G. J	1
Burnham, T. L	1
Butler, G	1

Packages received by the Smithsonian Institution, &c.—Continued.

INDIVIDUALS—Continued.

Cabas, A. G	1
Canby, W. M	1
Carpenter, P. P	1
Carey, H. C	3
Calterfield, W. F	2
Chandler, Prof. C. F	3
Chickering, jr., Prof. J. W	1
Clarke, Prof. H. C	1
Clarke, J. L	1
Cleveland, D	3
Clinton, G. W	1
Coffin, Prof. S. J	1
Colvin, V	4
Congdon, J. W	2
Conrad, T. A	1
Cook, Prof. G. N	1
Cope, E. D	13
Coues, Dr. E	13
Cox, E. T	8
Crozio y Berra, M	1
Curtis, Dr. J	1
Cutting, H. B	1
Dall, W. H	34
Dana, Prof. J. D	31
Dannfelt, J	1
Davidson, G	1
Davis, Admiral	1
Davis, H. C	2
Dawson, Prof. J. W	9
Dennis, J. S	1
Dike, C	2
Dobson, James	2
Dobson, John	2
Dodge, C. R	1
Dow, Capt. J. M	4
Downes, J	1
Draper, Dr. D	1
Draper, Dr. H	1
Dulton, Capt. E. C	1
Eastman, Prof. J. R	1
Eaton, Hon. J	1
Ellinwood, E. N	1
Elliott, E. B	2
Ellis, F. B	1
Endlich, Dr. F. M	1
Engelmann, Dr. G	5
Ericsson, Capt. J	2
Eve, Prof. P	1
Everdell, H	1
Farlowe, Dr. W. G	2
Fay, S	1
Felix, G	1
Ferrel, W	1
Firth, A	1
Fisher, Dr. G. J	1
Fiss, G. W	2
Force, Judge M. F	1
Foreman, Dr. E	2
Fortin, Hon. P	2
Fremont, Gen. J	13
Frost, G. H	1
Gabb, Prof. W. M	3
Garber, Dr. A. V	1
Garman, Dr. S. W	1

INDIVIDUALS—Continued.

Gentry, T. S	1
Gerard, W. R	1
Gilbert, G. K	2
Gill, Dr. T	18
Glover, T	1
Goodall, Professor	1
Goode, G. B	2
Goodfellow, E	2
Graham, Colonel	1
Gray, Prof. A	10
Guyot, Prof. A	13
Hagen, Dr. H	8
Hale, M. H	1
Hall, Prof. J	15
Harding, C. L	1
Harding, E	2
Harding G. W	2
Harkness, Professor	1
Harris, W. J	1
Hawkins, Col. R. C	1
Hayden, Dr. F. V	93
Haynes, Professor	1
Hedrick, B. S	1
Henry, Prof. Jos	36
Henshaw, H. W	1
Herbert, G	2
Higgins, E. S	2
Hilgard, Prof. J. E	3
Hill, G. W	1
Hill, Dr. T	1
Hilton, W	1
Hinrichs, Prof. G	15
Hitz, J	1
Hitchcock, Prof. C. H	1
Hoar, Judge	1
Holden, Prof. E. S	2
Hough, F. B	2
Howe, Dr. S. G	1
Hunnius, Adv	3
Hunt, Dr. T. S	3
Hyatt, Prof. A	2
Hyatt, Dr. E	2
Jackson, Lieut. H	3
Jarvis, Dr. E	21
Jenkins, Rear-Admiral T. I	2
Johnson, Captain	1
Juul, Partro O	1
Kerr, Prof. W. C	1
Kingston, Prof. G. T	1
Knox, J. J	1
Lapham, Dr. I. A	1
Law, J	1
Lawrence, G. N	5
Lawson, Captain	1
Lea, Dr. I	17
Le Conte, Dr. J. L	9
Lee, Admiral S. P	2
Lees, J. L	2
Leidy, Dr. J	13
Lemmon, J. G	2
Leonard, Prof. J. M	4
Lesley, J. P	5
Lesquereux, Prof. L	4
Levi, Bishop	1

Packages received at the Smithsonian Institution, &c.—Continued.

INDIVIDUALS—Continued.	
Levitte, Dr. G. M	1
Lewis, Dr. J	1
Loomis, Prof. E	11
Lovering, Prof. J	2
Lyman, B. S	5
Lyman, Dr. T	3
MacIntire, J	1
McMurtrie, Dr. W	2
Manigault, G. E	4
Marcou, Prof. J	11
Marsh, Prof. O. C	15
Marwedel, Miss E	1
Mason, Prof. O. T	1
Massey, A. A	1
Matthews, G. F	4
Meek, F. B	22
Meigs, Dr. J. A	4
Meigs, General M. C	1
Milner, J. W	5
Mitchell, Miss M	2
Mohr, C	1
Mohr, jr., P. F	2
Moody, J. D	1
Morais, Rev. S	1
Morris, Prof. G. S	1
Morse, E. S	1
Motley, J. L	1
Moyer, Dr. T. S	1
Munroe, H. F	3
Myer, General A. J	5
Nipher, Prof. F. E	1
Newberry, Prof. J. S	2
Newcomb, Prof. S	11
Newton, Prof. H. A	7
Nolan, Dr. E	1
Nourse, Prof. J. E	1
Olmstead, Rev. L. G	1
Osborne, J. W	1
Otis, Dr. G. M	1
Packard, jr., Dr. A. S	8
Paine, Hon. H. E	1
Parker, Dr. P	4
Parkman, F. A	1
Parry, Dr. C. C	2
Paterson, Captain	1
Pearson, J	8
Peck, C. H	1
Peirce, Prof. B	4
Peters, Prof. C. H. F	3
Pimental, F	1
Poesche, T	3
Poore, B. P	1
Pourtales, L. F. de	4
Powell, Maj. J. W	2
Prime, T	1
Putnam, F. W	3
Pais, Professor	2
Rau, Prof. C	5
Raymond, R. W	2
Read, General J. M	1
Redfield	1
Rhees, W. J	3
Ridgeway, R	5
Riley, C. V	5

INDIVIDUALS—Continued.	
Rillieny, N	1
Rittler, J	1
Roberts, G	2
Robinson, R. W	2
Rodrigues, Dr. J. C	1
Rogers, Professor	1
Ross, Dr. Alexander M	4
Rutherford, L. M	1
Safford, Prof. J. M	1
Safford, Prof. T. H	2
Salisbury, Prof. E. E	1
Sands, Rear-Admiral B. S	1
Schenck, Hon. R. C	1
Scheiffelin, H. M	1
Schott, C. A	3
Schroeder, Mrs. E	1
Schumacher, P	2
Schuster, H	2
Scudder, S. H	6
Seaman, W. H	1
Selwyn, A. R. C	4
Shaler, Prof. N. S	2
Shepard, Prof. C. F	1
Sigsbie, Capt. C. D	1
Silliman, Prof. B	7
Slater, jr., H. N	2
Smallwood, Dr. C	1
Smith, A	1
Smith, Prof. H. L	1
Smith, Prof. S. I	1
Smith, W. H	1
Snow, Dr. E. M. C	2
Southall, J. C	2
Squier, E. G	3
Starr, C D	3
Stearns, R. E. C	2
Sterling, C	1
Stimpson, F. E	1
Stone, Prof. O	2
Storrs, C	1
Stout, Dr. A. B	1
Strong, C. E	1
Swezey, G. D	2
Taft, R. C	2
Thomas, Prof. C	1
Thomson, J. H	9
Thornton, Sir E	1
Toner, Dr. J. M	2
True, Dr. N. J	1
Trumbull Dr. J. H	2
Tryon, jr., G. W	2
Tuckerman, Prof. E	4
Turrill, C. B	1
Uhler, Dr. P. R	2
Vasey, Dr. G.	3
Verrill, Prof. A. E	2
Vetromile, E	1
Wachsmuth, C	1
Wahl, Dr. W	1
Waterhouse, Dr. A	6
Watson, Prof. J. C	2
Weeden, W. B	2
Western & Co	2
Weston, H. C	2

Packages received by the Smithsonian Institution, &c.—Continued.

INDIVIDUALS—Continued.		INDIVIDUALS—Continued.	
Wheeler, Lieut. G. M	7	Winthrop, R. C	1
White, Dr. C. A	15	Witthaus, Mrs. R. A	1
Whiteanes, Prof. J. F	1	Woodrow, Rev. Prof. J	2
Whitney, Prof. J. D	6	Woodward, Dr. J. J	1
Whitney, Prof. W. D	10	Woodworth, Dr. J. M	1
Whittlesey, C	1	Worthen, Prof. A. H	9
Wilson, Dr. D	3	Yarrow, Dr. H. C	3
Wilson, J. O	1	Young, Prof. C. A	6
Winchell, Prof. A	6	Young, C. B	8
Winchell, N. H	2	Young, Mrs. M. J	2
Wines, Dr. E. C	1		

RECAPITULATION.

Total addresses of institutious	316
Total addresses of individuals	328
	644
Total number of parcels to institutions	3,705
Total number of parcels to individuals	1,148
	4,853

REPORT OF THE EXECUTIVE COMMITTEE.

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 1876, and the estimates for the year 1877.

Statement of the condition of the funds at the beginning of the year 1877.

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 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, now valued at	42,000 00
Cash balance in United States Treasury at beginning of year 1877	21,029 18
Total Smithson funds, January, 1877	714,029 18

Statement of receipts and expenditures of the Smithsonian Institution during 1876.

RECEIPTS.

Interest on $650,000 from the United States, 6 per cent. gold	$39,000 00
Premium on above June 30, 1876, at 111⅝, $2,266.87, and January 6, 1877, at 106$\frac{1}{16}$, $1,255.36, (less commission)	3,522 23
Interest on Virginia bonds, coupons sold December 15, 1876, @ 83–86, (less commission)	2,907 75
Dividend from First National Bank October 7, 1876, 25 per cent	2,056 23
Amount	47,486 21

EXPENDITURES.

Total expenditure from the Smithson income in the year 1876	46,978 21
Balance unexpended of the annual income, which is included in the cash balance in the Treasury, ($21,029.18)	508 00

HAMILTON BEQUEST.

Interest on $1,000 February 24, 1874, to December 31, 1874	$50 88
" January 1, 1875, to December 31, 1875	67 61
" January 1, 1876, to December 31, 1876	65 36
Total income received to 31st December, 1876	183 85
Expended for exploration of a cave near Carlisle, Pa., in 1876, by Prof. S. F. Baird	150 00
Balance on hand January 1, 1877	$33 85

VIRGINIA BONDS.

Amount realized from sale of Virginia coupons in 1876, by Riggs & Co.

December 15, 1876, coupons due 1st January, 1876, and 1st July, 1876:

30 coupons @ 85	$25 50	
12 coupons @ 86	10 32	
900 coupons @ 83⅛	748 13	
2,580 coupons @ 83	2,141 40	
	2,925 35	
Less ½ per cent., broker's commission	17 60	
		$2,907 75

FIRST NATIONAL BANK DEPOSIT.

Amount on deposit at the time of the suspension of the bank, 19 September, 1873			$8, 224 87
Received on account of the above—			
11th November, 1873,	30 per cent	$2, 467 46	
7th April, 1874,	20 per cent	1, 644 97	
5th May, 1875,	10 per cent	822 48	
27th December, 1875,	15 per cent	1, 233 73	
7th October, 1876,	25 per cent	2, 056 23	
	100		8, 224 87

Statement of expenditures in detail from the Smithson income, in 1876.

BUILDING.

Repairs and improvements	$2, 561 71	
Furniture and fixtures	704 62	
		$3, 266 33

GENERAL EXPENSES.

Meetings of the board	$300 75	
Lighting the building	365 28	
Heating the building	775 71	
Postage	320 64	
Stationery	525 71	
Incidentals, ice, insurance, carriage, printing, &c	860 57	
Salaries and clerk-hire	12, 541 97	
Purchase of books and periodicals	596 80	
		16, 287 43

PUBLICATIONS, RESEARCHES, ETC.

Smithsonian contributions	$7, 331 43	
Miscellaneous collections	3, 116 21	
Reports	603 50	
Map of United States, (for the Centennial Exhibition)	200 00	
Meteorology and researches	2, 124 34	
Apparatus	1, 241 59	
Laboratory	94 44	
		14, 711 51

EXCHANGES.

Literary and scientific international exchanges	10, 199 10

MUSEUM.

Advanced for construction of laboratory of natural history..	$1,313 84
Advanced for clerk at Centennial	1,200 00
Total expenditure from the Smithson income in 1876.	46,978 21
Expended from Hamilton-bequest income	150 00
	47,128 21

REPAYMENTS.

The Institution, as in former years, has made temporary advances for the payment of freight on Government collections, &c., the repayments of which, together with the amount received from sales of the publications of the Institution, have been deducted from the several items of the foregoing expenditure, as follows:

From exchanges, repayments for freight	$127 88
From postage, repayments	21 77
From researches, repayments	5 00
From Smithsonian Contributions, sales of publications	42 05
From miscellaneous collections, sales of publications	277 40
From reports, sales of publications	16 60
From stationery, repayment	3 00
From cost of books, repayment	29 04
From furniture, repayment	16 00
From building, repayment	3 75
From incidentals, repayment	50 00
Total	$592 49

ESTIMATES.

The following are the estimates of receipts and appropriations for the year 1877 of the Smithson fund:

Estimated receipts.

Interest on the permanent fund, receivable June 30 and December 31, 1877, in gold	$39,000 00
Probable premium on gold, (6 per cent.)	2,340 00
Interest on the Hamilton fund to December 31, 1877, in gold	60 00
Probable premium in gold, (6 per cent.)	3 60
Interest on Virginia bonds from sale of coupons due January 1 and July 1, 1877	2,500 00
	$43,903 60

Provisional appropriations.

For building	$1,000
For general expenses	14,000

For publications and researches	$18,000
For excnanges	8,000
For books and apparatus	2,000
For contingencies	500
	$43,500

NATIONAL MUSEUM.

The collections of the surveying and exploring expeditions of the Government forming the National Museum continue to be in charge of the Smithsonian Institution, Congress making annual appropriations for the care and preservation of the specimens. The estimate submitted for this purpose for the fiscal year ending June 30, 1877, was $25,000, but the amount granted was only $10,000. This large reduction in the appropriation rendered it necessary to discharge the larger portion of the scientific and laboring force of the museum, and to retain scarcely enough to exhibit and preserve the specimens without attempting any work in the way of making up sets of specimens for distribution to other museums, colleges, and academies.

To provide for the temporary storage of the large collections which would be received from the Centennial Exhibition, Congress at its last session granted to the Institution the use of an edifice on the mall, known as the "Armory building," and appropriated $4,500 for its repair. The building was in a dilapidated condition, and required all of this appropriation to put it in substantial repair, leaving nothing for heating and other arrangements. A small additional appropriation is recommended to be asked for at the present session of Congress to complete the repairs.

It was stated in the last report that it had been found necessary for properly carrying on operations connected with natural history, for which no conveniences existed in the Smithsonian edifice, that a separate building should be erected on the grounds; and the necessity for this was the more urgent on account of the large preparation of new specimens required for the Centennial Exhibition.

For this purpose $3,000 were granted by Congress. This sum was expended, but was found insufficient, and the remainder, to complete the building, was advanced from the income of the Smithson fund.

The amount thus advanced, $3,927.84, it is hoped, will be refunded to the Institution by an appropriation in the deficiency bill of this session.

The following is a tabular statement of the condition of the National Museum appropriations, January, 1877:

Appropriation for preservation of the Government collections for the fiscal year ending June 30, 1876, (Digest of Appropriations 1876, p. 105)	$20,000 00
Expenditure from July 1, 1875, to December 31, 1875	10,381 32
Balance unexpended January 1, 1876	9,618 68
Expenditure from January 1 to June 30, 1876	9,618 68

Appropriation for preservation of the Government collections for the fiscal year ending June 30, 1877, (Digest of Appropriations, 1877, p. 106)	$10,000 00
Expenditure from July 1 to December 31, 1876	5,090 86
Balance unexpended January, 1877	4,909 14

Appropriation for fitting up a separate building or laboratory for operations in natural history, (act July 31, 1876; Digest, 1877, p. 106)	3,000 00
Expenditure from July 1 to December 31, 1876	3,000 00

Appropriation "for repairing and fitting up the so-called Armory building on the mall, between Sixth and Seventh streets, and to enable the Smithsonian Institution to store therein and take care of specimens of the extensive series of the ores of the precious metals, marbles, building-stones, coals, and numerous objects of natural history, now on exhibition in Philadelphia, including other objects of practical and economical value, presented by various foreign governments to the National Museum, four thousand five hundred dollars: *Provided*, That the said sum shall be expended under the direction of the secretary of the Smithsonian Institution," (act July 31, 1876; Digest of Appropriations, p. 106)	4,500 00
Expenditure from July 1, 1876, to December 31, 1876	3,916 23
Balance unexpended January, 1877	583 77

All the payments on account of the National Museum have been made directly by the disbursing officer of the Department of the Interior, on the presentation of vouchers approved by the secretary of the Smithsonian Institution.

SUMMARY.

The executive committee have examined five hundred and forty-two vouchers for payments made from the Smithson income during the year 1876, and three hundred and nine vouchers for payments made from the congressional appropriations for the National Museum, making a total of eight hundred and fifty-one vouchers.

All of these vouchers have the approval of the secretary of the Institution, and a certificate setting forth that the materials and property and services rendered were for the Institution and to be applied to the purposes specified.

The committee have also examined the account-books of the National Museum, and find the balances of $4,909.14 and $583.77(=$5,492.91) to the credit of the Institution to correspond with the certificate of the disbursing clerk of the Department of the Interior.

The quarterly accounts-current, bank-book, check-book, and ledger, have also been examined and found to be correct, showing a balance in the charge of the Treasurer of the United States January 11, 1877, of $21,029.18.

Respectfully submitted.

PETER PARKER,
GEO. BANCROFT,
Executive Committee.

WASHINGTON, *January* 23, 1877.

JOURNAL OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION.

WASHINGTON, D. C., *January* 24, 1877.

A meeting of the Board of Regents of the Smithsonian Institution was held this day at 7 o'clock p. m. in the office of the Secretary.

Present, Chief-Justice Waite, Chancellor of the Institution; Hon. H. Hamlin, Hon. J. W. Stevenson, Hon. H. Clymer, Hon. G. W. McCrary, Hon. Peter Parker, Hon. George Bancroft, Prof. Asa Gray, and Professor Henry, the Secretary.

The minutes of the last meeting were read and approved.

Excuses for non-attendance were received from Professors Dana and Coppée.

The Secretary presented a general exhibit of the condition of the fund and the receipts and expenditures for the year 1876. He stated that to save time these statements and all the accounts of the Institution had been referred by him to the executive committee, who were prepared to report at the present meeting.

Dr. Parker, in behalf of the executive committee, presented the annual report of the receipts, expenditures, estimates, &c.

On motion of Mr. Hamlin, the report was adopted.

The Secretary called the attention of the Board to the great increase of the National Museum during the past year from specimens procured from the appropriation by Congress for the Centennial, from the donations of States of the Union, from individuals, and from foreign governments. He stated that for the exhibition of these articles an additional space of four times that afforded by the present Smithsonian edifice would be required; that therefore an additional building was absolutely necessary, and as this could not be erected out of the Smithson fund, an appropriation from Congress must be asked for.

On motion of Dr. Parker, the following preamble and resolution were adopted, and the Secretary was instructed to transmit them to Congress:

Whereas Congress, in the organization of the Smithsonian Institution, directed that it should make provision on a liberal scale for a museum to contain all the objects of natural history and of curious and foreign research, then belonging to or hereafter to belong to the United States Government; and

Whereas, in accordance with this direction, the Institution has developed and for many years principally supported this national museum, the collection being the property of the Government, while the building was erected for their accommodation at a cost of $500,000, out of the income of the Smithson fund; and

Whereas, on account of the appropriations of Congress for a national exhibit at the Centennial, and the liberal donations which have been made by several States of the Union, by individuals, and especially by foreign governments, the National Museum has suddenly increased to fourfold its previous dimensions, and far beyond the capacity of the Smithsonian building to contain it: Therefore,

Resolved, That Congress be respectfully requested to provide accommodations for these additional collections by the erection of a suitable building in connection with the present Smithsonian edifice.

Professor Gray, from the committee appointed at the last session, "to take into consideration the connection of the Smithsonian Institution and the National Museum, and to recommend such action as may be thought proper in relation to the matter," made report of progress and requested farther time, which was granted, it having as yet been found impossible to obtain a meeting of the committee for the consideration of the subject.

On motion of Mr. Clymer, the Board adjourned to meet on Thursday, February 1.

WASHINGTON, D. C., 1*st February*, 1877.

An adjourned meeting of the Board of Regents was held this day, at 7 o'clock p. m., in the office of the Secretary.

Present, Chief-Justice Waite, Chancellor; Hon. T. W. Ferry, Hon. H. Hamlin, Hon. J. W. Stevenson, Hon. A. A. Sargent, Hon. H. Clymer, Hon. B. H. Hill, Hon. Peter Parker, Hon. George Bancroft, Prof. Asa Gray, and the Secretary, Professor Henry.

The minutes of the last meeting were read and approved.

Mr. Sargent and Mr. Hill stated that they were unavoidably detained from the last meeting.

Professor Gray presented the following report of the special committee on the Museum:

REPORT OF SPECIAL COMMITTEE.

When Congress, thirty years ago, enacted the law which established this Institution, it probably did not anticipate the state of things to which we have arrived. The income of $500,000 must then have appeared much larger than it does now, and the several undertakings which were devolved upon it must have been contemplated upon a moderate scale, if it was supposed that the means would compass the ends. A library, upon which $25,000 annually might be expended, a gallery of art, a chemical laboratory, a geological and mineralogical cabinet, necessary lecture-rooms, and, by implication, lecturers, a museum of natural history and natural products, to include all the materials then belonging, and thereafter to belong, to the United States, (and we see how vast that item has become,) these all have assumed a magnitude far beyond what could have been contemplated; and yet they do not cover those operations for "the increase and diffusion of knowledge among men" which have given to the Smithsonian Institution its chief reputation and greatest usefulness throughout the civilized world.

The reasonable explanation of the terms of the organic law (and which those who were familiar with the discussions at the time know to be the true one) is, that Congress did not attempt to define the particular course which the Institution should take, probably because under the conflicting and incongruous views that were urged, it did not clearly see its way to do so. But while the law allowed all the available income to be devoted to a library, if the Regents should think proper to give the new establishment that direction, it required scientific cabinets, laboratories, &c., which looked to a certain amount of development upon a different line. The act indicated two or three allowable lines along which the Institution might develop, either of which would soon have absorbed all the income. Under it the Regents might have converted it essentially into a library, into an educational establishment, or into a museum. Under it they also might, still fulfilling the required conditions, develop lines of operation which come closer to the express intent of the founder, which intent must have been the governing principle of the whole enactment. And this is what our predecessors did. It is not surprising that this small body, having the responsibility laid upon it, should have adhered as closely as possible to the terms of Smithson's will "founding an establishment for the increase and diffusion of knowledge among men." We believe that the propriety and the wisdom of their course, confirmed by the results, is now unquestioned.

That the museum and other collections mentioned in the act of establishment must have been regarded as a subsidiary feature, and the library equally so, (except upon the alternative of its having the lion's share,) would seem evident from the fact that these were to be maintained upon the income of the Smithsonian fund, while the objects composing them belonged, and appear still to belong, to the Government of the United States, and to be held in charge of the Institution for exhibition and study. Accordingly, when these collections increased to such extent that the care and exhibition of them threatened to absorb a large part of the income of the Smithson fund, and to cripple legitimate operations for the increase and diffusion of knowledge, which the Regents had at the outset originated, and of which experience had shown the wisdom so soon, we say, as these Government collections began to press heavily upon the institution, Congress, being informed thereof, made provision for assuming this burden. It has made increasing provision as the collections have themselves increased in magnitude and cost of maintenance. It has thereby manifestly acted upon the theory that these museums are national property. The alternative view, viz, that they are gifts, supplemented with gifts for their support, would be fatal to the Institution, for the objects remain, continually increase, and cannot be declined, while the gift for their maintenance may at any time cease to be made. Upon this theory, Congress could at any time convert this Institution into a museum, and that without any legislation whatever, by merely omitting to make an annual appropriation. For, without taking into account the vast Centennial gifts of foreign countries, the collections will now more than fill the Smithsonian building, and their care and exhibition would absorb its whole income.

We are therefore bound to conclude that the Board of Regents, as respects these national collections, acts as the trustee of Congress. Under this state of things, and in view of the ever-increasing magnitude and interest of these collections, the relation of this Institution to the National Museum becomes a matter for grave consideration.

In contemplating it we should be mindful of a policy which the Regents have pursued of economizing the means and energies of the Institution by doing all it can through others; by taking up no line of usefulness, however inviting, which is otherwise provided for, and even relinquishing important fields upon which it had entered, whenever other agencies were at work in them and were found adequate to occupy them. Thus the important field of meteorology, upon which, at the outset, the Institution systematically entered, was surrendered to the Signal Bureau, which Congress has enabled to cover the ground. To avoid needless duplication of books and librarians, it has consolidated its library with that of Congress, and contributes to the latter the complete series of transactions of learned societies, journals, and other publications which it receives by exchange, or from time to time may purchase, not parting, however, with the right of property, and thus continuing to fulfil, according to its best judgment, the duty of making provision "for the gradual formation of a library composed of valuable works pertaining to all departments of human knowledge." So also when Mr. Corcoran founded a gallery of art, and endowed it with double the amount of the original Smithsonian fund, our unimportant collections in that department were contributed to it, and the Institution may now fairly hold itself absolved from the duty of maintaining "a gallery of art."

Our Secretary, in his annual report submitted on the 26th of January, 1876, has now raised the grave question whether the well-being of the Institution would not favor or even require the adoption of a similar policy as regards the National Museum. He declares that it is most "desirable that a more definite distinction between the two establishments, if not an entire separation, should be made," and he urges the subject upon our attention by considerations which cannot be disregarded.

Your committee was appointed to take thought upon this subject. The vast increase of museum objects in natural history, ethnology, and materials of industrial art, consequent upon the Centennial Exposition, an increase far beyond the largest anticipations, gives new importance and urgency to this question.

A favorable action by the present Congress upon the suggestion made to it by a resolution of this Board, at the last meeting, viz, for the erection of a large but comparatively inexpensive building, annexed to the present edifice, to contain these great accessions to the museum, would do away with the present embarrassment in that regard. The suggested acquisition by Government of the present Smithsonian edifice, already mainly filled with its collections, would give a desirable unity and prominence to the National Museum, and might sufficiently mark that "definite distinction between the two establishments" which our Secretary suggests as needful. We agree that a more marked distinction than now appears to exist is desirable, for the avoidance of present misapprehension and future complication.

But we apprehend that both these desirable changes may not sufficiently provide against the danger that the Smithsonian Institution may become wholly subsidiary to the museum, and be perhaps crippled by it. The Institution has only one executive officer, with undivided responsibility, who may, with our consent, "employ assistants," but we look to him alone, and all must pass through his hands. His scientific labors in conducting the Institution, not to speak of those somewhat extraneous, of which he might possibly be relieved, are various, important, and exacting. Much will be lost if the executive head of this Institution shall be other than a man of broad scientific culture and experience, commanding the regard of the scientific world, and the confidence of the many who depend upon his judgment. His time and powers must be divided between such duties as are here referred to, and those of administration. Now the proportion which the museum bears to the Institution proper is already large, and it threatens to be predominant. We have no desire to check its immense development, and we contemplate with satisfaction its sure popularity; but, as respects the burden which the museum throws upon our Secretary, we may say that it is already heavy, and that it threatens to be injuriously large. If not provided against, the time seems sure to come when the museum will mainly absorb the working energies of the Institution.

In the next place we must all agree that the looking after congressional appropriations in the present mode is not desirable. The Secretary has called attention to this. An objectionable feature would be removed if the appropriations were made directly in the name of the National Museum, and if it became possessed of the present edifice. But still the duty of preparing or supervising and of anxiously furthering the annual appropriations for the museum, would devolve upon our Secretary.

We would also remark that this great museum must have a large number of employés, many times more than the Institution itself needs for its uses. This great extension of patronage cannot be contemplated without anxiety. Under the present organization this patronage is vested in the Secretary. So far as the Institution is concerned, it were much better not to have it. On the other hand it may well be that the

Government would prefer some such administration of the museum as this board secures.

No present action is proposed by this committee, beyond the recommendation that the distinction between the Institution itself and the museum under its charge should be mads as prominent as possible. The very great development which the museum is now undergoing may soon bring the whole subject before the Board in a practical form. If the next Congress should adopt a plan to which the Secretary adverts, (but which seems unlikely,) namely, that of transferring the museum to a new building to be erected for the National Library, the separation which the Secretary recommends would be at once complete. In that event, since the Smithsonian building was erected in great part for containing these collections, we will not doubt that Congress would indemnify the Institution by re-imbursing an equitable portion of the original outlay. On the other hand, if the museum is to develop to its full size and importance upon the present site, according to the plans laid before the Board, and by it recommended to Congress, this will, as it seems to us, almost necessarily involve the acquisition by the Government of our present edifice; and that will pave the way for an entire separation of administration, or to such other adjustment as the Board of Regents may then think best, or be able to accomplish.

Respectfully submitted by

ASA GRAY,
A. A. SARGENT,
HIESTER CLYMER,
Committee.

On motion of Mr. Stevenson, it was

Resolved, That the report of the committee be received and printed in the proceedings of the Board of Regents, to be submitted to Congress with the report of the Secretary.

The Secretary presented his annual report of the operations of the institution during 1876, which was read, and, on motion, ordered to be transmitted to Congress.

The Secretary also presented a list of the articles given to the United States National Museum by foreign governments represented at the Centennial Exhibition in Philadelphia.

On motion of Mr. Hamlin, it was

Resolved, That a committee be appointed to prepare a memorial to be submitted to Congress, showing the recent immense contributions to the national collection, and the necessity for provision being speedily made for their reception and exhibition.

The Chancellor appointed Messrs. Bancroft, Parker, Gray, and the Secretary.

On motion, the Board adjourned to meet at the call of the Secretary.

WASHINGTON, *February* 5, 1877.

A meeting of the Board of Regents was held this day at 7 o'clock p. m., in the office of the Secretary.

Present, Chief-Justice Waite, Chancellor; Hon. T. W. Ferry, Hon. J. W. Stevenson, Hon. A. A. Sargent, Hon. H. Clymer, Hon. G. W. McCrary, Hon. P. Parker, Hon. Geo. Bancroft, and the Secretary.

The minutes of the last meeting were read and approved.

Mr. Bancroft, from the special committee appointed at the last meeting, presented the following report of a memorial to be sent to Congress:

MEMORIAL

To the Senate and House of Representatives of the United States of America in Congress assembled.

The undersigned, Regents of the Smithsonian Institution, beg leave respectfully to lay before you a question which has suddenly arisen, and which can be solved only by your authority.

In the year 1846, on the organization of the Smithsonian Institution "for the increase and diffusion of knowledge among men," Congress, to the great relief of the Patent-Office and other public buildings, devolved upon the Regents of that Institution the custody of "all objects of art and of foreign and curious research, and all objects of natural history, plants, and geological and mineralogical specimens belonging or hereafter to belong to the United States, which may be in the city of Washington."

In accordance with this enactment, the Institution has received and carefully preserved all the specimens which have been brought together from more than fifty public exploring expeditions, and has added specimens collected by itself, or obtained from foreign museums by exchange, till its present edifice, in the beginning of 1876, had become full to overflowing.

By an act bearing date July 31, 1876, additional duties were laid upon the Smithsonian Institution as custodian, and $4,500 were appropriated "for repairing and fitting up the so-called Armory building, on the mall between Sixth and Seventh streets, and to enable the Smithsonian Institution to store therein and to take care of specimens of the extensive series of the ores of the precious metals, marbles, building stones, coals, and numerous objects of natural history now on exhibition in Philadelphia, including other objects of practical and economical value presented by various foreign governments to the National Museum."

As a fruit of this act of the General Government, the Smithsonian Institution finds itself the custodian of enormous collections that had been displayed at the Centennial Exhibition, and on the closing of that exhibition, had been presented to the United States. These donations are made by individuals among our own citizens, by foreign exhibitors, and by several of the States of the Union, and there is scarcely a power in the civilized world in any region of the globe which has not taken part in these contributions, and some of them with the largest generosity. Men of science, most competent to pass judgment, pronounce them to be of immense value, and are of opinion that, including the gifts from States of the Union and the exhibits of the United States, they could not have been brought together by purchase for less than a million of dollars.

That the magnitude and value of the donations from foreign governments may be manifest, we annex to this memorial the list of the more important of them, as prepared by Prof. S. F. Baird, who represented the Smithsonian Institution at Philadelphia. Their adequate exhibition requires an additional building, which shall afford at least four times the space furnished by the present edifice of the Institution.

The Government of the United States is now in possession of the materials of a museum, exhibiting the natural products of our own country, associated with those of foreign nations, which would rival in magnitude, value, and interest the most celebrated museums of the old world.

The immediate practical question is, shall these precious materials be for the most part packed away in boxes, liable to injury and decay, or shall they be exhibited?

It was the act of Congress which ordered the acceptance in trust of these noble gifts to the United States. The receiving of them implies that they will be taken care of in a manner corresponding to the just expectations of those who gave them; and one of the prevailing motives of the donors was that the productions of their several lands might continue to be exhibited. The intrinsic value of the donations is moreover enhanced by the circumstances under which they were made. They came to us in the one-hundredth year of our life as a nation, in token of the desire of the governments of the world to manifest their interest in our destiny. This consideration becomes the more pleasing when we bring to mind that these gifts have been received not exclusively from the great nations of Europe from which we are sprung, or from the empire and republics on our own continent beyond the line, but that they come to us from the oldest abodes of civilization on the Nile, from the time-honored empires and kingdoms of the remotest Eastern Asia, and from the principal states which are rising into intellectual and industrial and political greatness in the farthest isles and continent; from states which are younger than ourselves, and bring their contributions as a congratulatory offering to their elder brother.

We have deemed it our duty to lay these facts and reflections before both houses of Congress, and to represent to them that if they in their wisdom think that this unequaled accumulation of natural specimens and works interesting to science, the evidence of the good-will to us that exists among men, should be placed where they can be seen and studied by the people of our land and by travelers from abroad, it will be necessary to make an appropriation for the immediate erection of a spacious building. Careful inquiries have been instituted to ascertain the smallest sum which would be adequate to that purpose; and the plan of a convenient structure has been made by General Meigs, the Quartermaster-General United States Army. We beg leave further to represent that to accomplish the purpose there would be need of an appropriation of $250,000. This amount is required, not as a first installment to be followed by others, but as sufficient entirely to complete the edifice. Should this appropriation be made at an early day, the building could be ready for the reception of articles before the next session of Congress.

On motion of Mr. Stevenson the report of the committee was adopted, and all the Regents present signed their names to the memorial,* which was placed in the hands of Mr. Stevenson to be presented to the Senate, and Mr. McCrary to the House of Representatives.

Mr. Clymer offered the following resolution, which was unanimously adopted:

Resolved, That the executive committee be authorized and requested to have a life-size portrait of the Secretary of the Institution painted by some competent artist, which, when finished and approved by the Regents, shall be preserved and kept in testimony and memory of the devoted, unselfish, and renowned services of Joseph Henry in behalf of the "increase and diffusion of knowledge among men."

The Board then adjourned *sine die*.

The following is the list appended to the foregoing memorial:

List of the more important collections presented by foreign commissioners to the United States Government and taken charge of in behalf of the National Museum by the Smithsonian Institution.

ARGENTINE REPUBLIC.

Dr. ERNESTO OLDENDORFF, *Commissioner*.

Ores of metals, minerals, pottery, tiles, stuffed animals, leathers and hides, nets, fishery products, samples of woods, fibers, seeds, grains, specimens of silk and wool in great variety. This donation embraces almost the whole of the exhibit in Agricultural Hall and a large portion of that in the main building.

AUSTRIA.

Dr. FRANCIS MIGERKA, *Commissioner*.

Specimens of mineral wax (ozockerite) and a variety of mineral and industrial products.

BELGIUM.

Count D'OULTREMONT, *Commissioner*.

Some specimens of industrial products.

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* M. R. Waite, T. W. Ferry, H. Hamlin, J. W. Stevenson, A. A. Sargent, Heister Clymer, B. H. Hill, G. W. McCrary, Peter Parker, Asa Gray, George Bancroft. Regents of the Smithsonian Institution.

BRAZIL.

Dr. J. M. Da Silva Coutinho, *Commissioner.*

Specimens of iron, coal, hides, leather, tiles, and pottery in great variety; specimens in large number of woods, vegetable fibers, substances used as foods, gums, resins, &c. This collection embraces nearly the whole of the immense display in the agricultural building and a part of that in the main building.

CHILI.

Edward Shippen, Esq., *Commissioner.*

A collection of minerals and ores, artificial stone, tiles, terra cottas, and an extensive variety of grains, seeds, and other vegetable products, embracing by far the largest part of the display of the Chilian government in the main building.

CHINA.

J. L. Hammond, *Commissioner.*

The entire exhibit made by the commissioners of customs of China and displayed in the mineral annex. It includes a complete representation of the manners and customs of the Chinese, such as samples of their foods, medicines, clothing, their domestic and household utensils, their ornaments, objects used in their plays and festivities, &c. In the collection are numerous full-sized figures, beautifully executed and suitably dressed, representing the different ranks and classes in the community. Many hundreds of clay figures, about one foot in height, illustrating the different races of the empire; specimens of cotton and silk in great variety, samples of paper, leather, and the like; samples of pottery, such as vases, tea-pots, pipes; matting, baskets, &c. This collection is of unparalleled interest, and cost the Chinese government a large sum of money. It will require a space fully equal to half of one of the halls of the National Museum for its exhibition. There are also three ornamental gateways, three cases, and two pagodas as used in the main building for purposes of exhibition; musical instruments, specimens of wrought iron and other metals, bamboo-ware, glass, specimens of tea, oils, and woods, tobacco, and sugar. The entire collection (exclusive of the ornamental gateways and cases) filled twenty-one large wagon-loads.

EGYPT.

E. Brugsch, *Commissioner.*

Collection of minerals, tiles, and pottery; garden products in great variety; samples of wood, and a large collection of objects illustrating the habits and customs of the natives of Soudan, Nubia, and Abyssinia, such as musical intruments, weapons, clothing, &c.

FRANCE.

Captain Anfrye, *Commissioner.*

No collective exhibit was made by the government, but Messrs. Haviland, of Limoges, France, presented a pair of Centennial memorial-vases, valued at $17,000, and requiring the erection of a special kiln for their production, together with a large panel of tiles.

GERMANY.

Mr. BARTELS, *Commissioner.*

Specimens of tiles, cements, asphalt-work, fire-bricks, manufactures in metals and woods from the commissioner; and from Mr. F. Krupp, of Essen, a very extensive display illustrating the mineralogy and metallurgy of the iron-trade of Germany, with samples of the different manufactures made at the great gun-works at Essen. This collection is one of the largest and most complete at the Exhibition, and attracted great attention. A special catalogue of this collection was printed by the exhibitor.

HAWAII.

H. R. HITCHCCCK, *Commissioner.*

Collections of the volcanic and other rocks and minerals, ropes and fibers, tobacco, sugar, oils, models of boats, nets, and vegetable products in large variety.

ITALY.

JOSEPH DASSI, *Commissioner.*

Samples of alabaster, terra cotta, marbles, &c.

JAPAN.

Lieut.-General SAIGO TSUKMICHI, *Commissioner.*

A valuable series of tiles and other pottery, the large exhibit of the fisheries of Japan in the agricultural building, including both products and apparatus, skins and hides of animals, various food preparations, and a series illustrating the materials and manipulations employed in the manufacture of tea and silks; also manufactures of bamboo.

MEXICO.

Dr. MARIANO BARCENA, *Commissioner.*

The greater part of the exhibit of the natural products of the country as shown in the main building, including the ores of gold and silver, obsidian, woods, fibers, and other vegetable products, pottery and terra cotta. Among the most notable mineral specimens may be mentioned an iron meteorite, weighing 4,000 pounds.

NETHERLANDS.

Dr. E. H. VON BAUMHAUER, *Commissioner.*

Agricultural products in considerable variety; specimens illustrating the fisheries of Holland, including cod-liver oil, &c.; tiles, cement, &c.

NORWAY.

WM. C. CHRISTOPHERSEN, *Commissioner.*
GERHARD GADE, *Assistant Commissioner.*

A very large collection of ores and other specimens illustrating the metallurgy of iron, copper, nickel, &c. A collection illustrating the eatable fishes of Northern Europe; samples of prepared fishes, samples of food preparations, &c. Great variety of agricultural products.

ORANGE FREE STATE.

CHARLES W. RILEY, *Commissioner.*

A collection of agricultural products.

PERU.

JOSÉ CARLOS TRACY, *Commissioner.*

A series of the principal food and other vegetable products in that country.

PORTUGAL.

M. JAYME BATALHA REIS, *Agricultural and Colonial Commissioner.*
M. LOURENÇO MALHEIRO, *Industrial Commissioner.*

The greater part of the very extensive exhibit of minerals, ores, &c., in the main building; also pottery, samples of industrial products, glass-works, paper, &c., and a full series of the vegetable productions of the kingdom in nearly two thousand varieties. A portion only of this collection filled sixty large boxes.

RUSSIA.

General CHARLES DE BIELSKY, *Commissioner.*
Captain NICHOLSKY and Captain SEMETSHKEN, *Assistant Commissioners.*

An enormous collection illustrating the metallurgy of copper and iron, including different varieties of Russian iron and steel; the very extensive collection of minerals of Siberia, exhibited by the School of Mines and valued at a high price; samples of rope and cordage, pottery, tiles, cement, isinglass, and other products of the sturgeon.

SPAIN.

Col. F. LOPEZ FABRA, *Commissioner.*

A collection of great magnitude, illustrating the mines and mining of coal, iron, copper, and silver, salt, &c., in the kingdom of Spain; a very large number of bricks, tiles, earthenware, and pottery; illustrations of the various fibers and other materials for basket-work, cordage; industrial products in great variety, including samples of paper, leather, &c. A complete series illustrating the agricultural resources of the country.

From the Philippine Islands, as one of the colonies of Spain, were received, through Mr. Sebastian Vidal, samples of native work in the form of baskets, nets, boats, &c., and hemp fibers.

SWEDEN.

C. JUHLIN-DANNFELT, *Commissioner.*

The entire exhibit of Sweden made in the agricultural department illustrating the fisheries and agriculture of Sweden, including also specimens of fish, food-fish preparations, &c.; specimens of peat-working machinery, apparatus for deep sea sounding and dredging, and also for collecting specimens of natural history, photographs of Arctic scenery, &c

SIAM.

No Commissioner.

A collection illustrating the products, the industries, &c., of the kingdom of Siam, made for the Centennial Exhibition with the understanding that it should be presented to the United States at the close. This filled 216 boxes, and embraces many articles of great pecuniary value. This collection, with those from China and Japan, will require a room as large as the upper floor of the Smithsonian Institution for satisfactory display.

SWITZERLAND.

Mr. EDWARD GUYER, *Commissioner.*

Specimens illustrating the geology of the Alps and St. Gotthard tunnel.

TURKEY.

G. D'ARISTARCHI BEY, *Commissioner.*

Illustrations of the metal-work of the country, of its mines and minerals, its tiles and pottery, domestic and household utensils, samples of iron and steel, &c.

TUNIS.

G. H. HEAP, Esq., *Commissioner.*

A threshing-machine such as has been used from the time of the ancient Carthagenians.

UNITED KINGDOM OF GREAT BRITAIN AND IRELAND, INCLUDING COLONIES.

GREAT BRITAIN.

Col. H. B. SANDFORD, *Commissioner.*

A very large collection of the private exhibits of tiles, terra cottas, bricks, and pottery, sanitary ware, as also many industrial products in great variety; among the more notable articles in the series are collections of tiles and mosaics from Messrs. Minton & Hollins, and many specimens from Messrs. Doulton, of Lambeth; among them several large vases. Some highly important deposits have also been made, subject to recall after a certain period. Chief among these is the allegorical representation of America, a duplicate of that furnished by the Messrs. Doulton to the Albert Memorial in London, embracing several colossal figures. This group is valued at $15,000. Also the large terra cotta pulpit and font, and many other specimens of great variety; an extremely complete and important collection of samples of wools from all parts of the world, presented by Messrs. John L. Bowes & Brothers, embracing over three hundred varieties, each suitably labeled with prices marked, &c.; a similar collection of wools in the fleece exhibited by Messrs. James Oddy & Sons.

BERMUDA.

A. A. OUTERBRIDGE., Esq., *Commissioner.*

A great variety of specimens of coral, shells, and other marine objects, models of boats, samples of stone and wood.

CANADA.

Prof. A. L. SELWYN, *in charge of geological exhibit.*

An extensive collection of the rocks of British North America; many hundreds of specimens exhibited by the geological survey, specimens of coals from all parts of the Dominion; ores of different kinds, samples of iron, steel, and copper, stoneware, and pottery.

NEW SOUTH WALES.

AUGUSTUS MORRIS, Esq., *Commissioner.*

The extensive exhibit illustrating the mining resources, the natural history, and the botany and agriculture of the province, including a large model of the gold products of the colony up to the year 1875, and specimens of coal-oil, shale, petroleum, &c.

NEW ZEALAND.

JAMES HECTOR, Esq., *Commissioner.*

The entire exhibit of the animal, vegetable, and mineral kingdoms of the colony, and also specimens illustrating its ethnology. Among these specimens is a model of the gold product of the colony, and specimens of its coal.

QUEENSLAND.

ANGUS MACKAY, Esq., *Commissioner.*

Model of the gold product of the colony, specimens of ores of copper, iron, and gold; a large collection of native woods, fibers, and other products.

SOUTH AUSTRALIA.

S. DAVENPORT, Esq., *Commissioner.*

A full series of all the exhibits from the animal, mineral, and vegetable kingdoms.

TASMANIA.

H. P. WELCH, Esq., *Commissioner.*

Specimens of the iron and other ores, leather, woods, seeds, and grains, fibers, wools, &c.

VICTORIA.

Sir REDMOND BARRY, *Commissioner.*

The entire collection of useful economical minerals of the country exhibited by the mining department, specimens of stoneware and other products, extensive collections of grains, wools, fruits, fibers, and woods; samples of paper, gums, &c.

VENEZUELA.

MR. LEON DE LA COVA, *Commissioner.*

The entire exhibit made by this country of minerals, ores, articles of materia medica, fruits, fibers, extracts, &c.

In general it may be stated that from the countries mentioned in the foregoing, the exhibits made by the commissioners in behalf of their respective governments, so far as relates to the animal, vegetable, and mineral kingdoms, and their applications have been presented to the United States; in some cases without any exception whatever, in others all except a few duplicates which were presented to other foreign commissions, or to institutions in the United States. Indeed, the only countries from which absolutely nothing was received were, Denmark, Luxembourg, Bahamas, British Guiana, Cape of Good Hope, and Jamaica; the exhibit of these countries being either entirely private property or borrowed from the colonial museum in London, and necessarily returned.

EULOGY ON GAY-LUSSAC.

By M. Arago.

INTRODUCTION.

The biography which I am about to read is of unusual length, notwithstanding the numerous excisions I have made in it this very morning. I might, as an excuse, say that Gay-Lussac is no ordinary academician; that he will occupy a very eminent position in the scientific history of the first half of the nineteenth century; that the titles alone of the important memoirs he has published would fill a large number of pages, &c., &c.; but, I prefer frankly acknowledging it, I was too late in discovering that I had exceeded the established limits, and when there no longer remained the necessary time for giving a new form to my work. I therefore resign myself unreservedly to any criticisms that the subject may call forth. I will merely observe to all those who, coming here to seek relaxation, should unfortunately only find weariness, that an old man, drawn into dwelling even to garrulity upon the divers merits of a friend, has perhaps some claim to indulgence.

CHILDHOOD OF GAY-LUSSAC—HIS ADMISSION TO THE POLYTECHNIC SCHOOL.

Joseph Louis Gay-Lussac, one of the most illustrious scientists of which France can boast, was born, September 6, 1778, at Saint Leonard, a small town of the ancient province of Limousin, situated near the frontier of Auvergne. His grandfather was a physician, and his father king's procurateur (prosecutor) and judge at Pont de Noblac.

Those who have had an opportunity of observing the frigid reserve which characterized Gay-Lussac in mature age will be undoubtedly surprised to hear me say that in his childhood he was boisterous, turbulent, and very venturesome. To justify my appreciation, I will cite one fact from a thousand which I have gathered from the lips of Gay-Lussac himself, and which was also related to me by his relatives: A venerable curé, uncle of our future associate, occupied a house only separated from that of Gay-Lussac's family by a small yard; he had established his fruitery in a room on which looked the chamber where Gay-Lussac and a brother, a year younger, were in the habit of studying. A desire to taste the forbidden fruit took possession of Gay-Lussac. He hurriedly stretches, with all imaginable difficulty, a pole from the window of this room to that of the good curé; and armed with a stick, to the end of which the blade of a knife was securely attached, he places himself astride upon the fragile bridge; the end of his excursion reached, he breaks a window-pane, pierces the finest of the fruit with his instrument, and returns triumphant, safe and sound, to his own apartment. This exploit, which might have cost him his life, was repeated several times at short intervals. Finally, Gay-Lussac's parents suspected the truth, and the two brothers were taken to the priest to ask pardon. The first thought of the child was to deny, but the evidence of his guilt became clear. Gay-Lussac experienced such humiliation at being surprised in the very act of telling a falsehood that he resolved never again to depart from the truth, a resolution religiously kept during the rest of his life. Those who like to seize, in the boyhood of great men, indications of the character exhibited later in life, will pardon me if I interrupt for a moment the order of dates to relate another anecdote remembered by our associate with very natural pleasure; this likewise involves a question of apples.

Gay-Lussac having gone to Paris, the superintendent of the school in which he was placed one day discovered that several apple-trees in his garden had been completely stripped. As the offense could not, he thought, be attributed to the pupils, since in order to pass from the yard to the garden, it was necessary to climb two high walls, he resolved to dismiss the servants. Gay-Lussac learns this, solicits and obtains an interview, and then exclaims, "The servants are innocent; it is the pupils who have taken your fruit. I will not tell you who took part in the raid, but I am sure of the fact since I was one." Let us add that the exceptional frankness of the youthful Gay-Lussac was not on this occasion followed by any serious consequences. It won for him, on the contrary, the most marked affection of the superintendent and his wife, who, from this time, lavished upon him truly parental care.

Gay-Lussac began the study of the Latin language under the direction of a priest who resided in Saint Leonard, for whom he always testified the sincerest attachment. That his taste for the noisy pastimes of youth might not interfere with his desire to perform his duties, he devoted a portion of the night to study, after playing all day with his comrades.

The revolution of 1789, so legitimate in its objects, and which began with so much grandeur and majesty, had ended by rushing into the most deplorable digressions. The law against suspicious persons reached Gay-Lussac's father. The removal of this excellent man to Paris would probably have been followed by his death. Our friend, filled with alarm, repaired diligently to the club, which met in his native town. to ascertain the slightest indication which could threaten his father. The sight of a strong and valiant youth inspired the leaders of the epoch with a desire to enroll him in the army, then fighting the

Vendeans. Gay-Lussac might gladly have donned the military capote and shouldered his musket, but his filial affection prevailed; he proved that, according to the letter of the law (he was but fifteen years of age) he was exempt from joining the defenders of the republic, and he was left undisturbed. After the ninth thermidor, Gay-Lussac's father, who had fortunately remained in the prisons of Saint Leonard, regained his liberty. The first use he made of it was to devote himself to the future of the highly-gifted son, who, during his imprisonment, had given him the most intelligent proofs of love. He placed him at M. Savouret's school in Paris.* This was in 1795. The scarcity and impossibility of procuring food for his pupils induced M. Savouret to close his establishment. Gay-Lussac was soon after received into the boarding-school of M. Sensier, which, established first at Nanterre and afterward at Passy, outside of the walls of Paris, enjoyed some advantages of which the schools of the capital were deprived at that time.

I have recently met in our assemblies old college-mates of Gay-Lussac, and all have preserved the most pleasant recollections of him. One of them, M. Darblay, a representative of the people, said to me, with feeling: "He was the model of his school-fellows; we never saw him, notwithstanding his uncommon spirit, give way toward any one to an impulse of anger or impatience; as to his diligence, that was never relaxed." A pupil, taken to the theater by his friend, when asked at what hour he returned, would reply: "I do not know, but it must have been very late, as there was no light in Gay-Lussac's chamber."

The difficulties under which M. Savouret had succumbed very soon reached M. Sensier himself. Of all his pupils, he alone retained Gay-Lussac, whose parents secretly were in the habit of sending him small quantities of flour. Reduced to the most cruel extremities, Madame Sensier every night carried to Paris, for sale, the milk of two cows, fed in her garden, but the road being unsafe, Gay-Lussac begged and obtained the favor of daily escorting his benefactress, armed with a large sword suspended to his belt. It was during the return, which was made by daylight, that our friend, stretched on the straw of the cart of the impromptu milk-woman, studied geometry and algebra, thus preparing himself for the examinations for the Polytechnic School, which he was soon to undergo.

The sixth Nivôse, year VI, after brilliant examinations, Gay-Lussac received the much-coveted title of pupil of the Polytechnic School. We see him in this establishment always conversant with the required duties, and giving during the hours of recreation private lessons to young men who were intended for public services. It was in this way he added small sums to the thirty francs that each pupil of the original Polytechnic School received as his monthly allowance, and that he suc-

* I regard as a duty the preservation in this biography of the names of all persons who had any relations with our friend in his youth.

ceeded in maintaining himself in Paris without imposing fresh sacrifices on his family.

Gay-Lussac was one of the most distinguished of the scholars of the Polytechnic School, as, at a later period, he was one of the most illustrious and popular of the professors.

DÉBUT OF GAY-LUSSAC IN CHEMISTRY—HE BECOMES COLLABORATOR OF BERTHOLLET AND ASSISTANT PROFESSOR OF THE FOURCROY COURSE—AERONAUTIC VOYAGE WITH M. BIRT.

Berthollet, who had returned from Egypt with General Bonaparte, requested, in 1800, a pupil from the Polytechnic School, whom he wished to make his aid in the work of the laboratory. Gay-Lussac was this privileged pupil. Berthollet suggested to him an investigation whose results were diametrically opposite to those expected by the illustrious chemist. I could not venture to affirm that Berthollet was not somewhat disturbed at finding himself mistaken in his predictions, but it is certain that, unlike many other scientists whom I could name, after the first impulse of vexation, the frankness of the young experimentalist only served to increase the esteem that the author of *Static Chemistry* had already conceived for him. "Young man," said he to him, "your destiny is to make discoveries; henceforth you shall be my collaborator. I desire, and it is a title of which one day I am sure I shall be able to boast, I desire to be your father in matters of science."

Some time afterward, without giving up his position with M. Berthollet, Gay-Lussac was chosen assistant professor of the Fourcroy course and often supplied Berthollet's place, which soon gained him the reputation, that was constantly growing, of one of the most distinguished among the very able professors at that time collected at the capital.

Man, by reason of his weight and limited muscular force, seemed condemned to move forever on the surface of the earth, and only to be able to study the physical properties of the elevated regions of our atmosphere by painfully climbing to the summit of mountains; but what are the difficulties over which genius allied to perseverance cannot triumph?

A scientist, who was a member of this academy, Montgolfier, calculated that by rarefying, by means of heat, the air contained in a paper balloon of limited size, he would obtain an ascensional force sufficient to raise men, animals, and instruments of all kinds. This idea was partially realized, June 1783, in the town of Annonai. The astonished Parisian population saw, November 21, of that same year, the intrepid voyagers, Pilatre de Roziers and d'Arlandes, sail through the air, suspended from a montgolfière. Another physicist, whom the academy has also numbered among its members, Charles, showed the possibility of making balloons of a varnished material almost impermeable to hydrogen, the lightest of known gases, which could take the place of heated air with advantage. From his voyage made December 1, 1783, in company with Robert the artist, in a balloon thus inflated, date ascensions infinitely less adventurous, and which in our day have become a pastime for idlers.

It is to the original Academy of Sciences we must likewise go back, if we wish to find one of the first scientifically useful ascensions made with hydrogen-gas balloons.

It seemed to result from the experiments made during an ascension by Robertson and Lhoest at Hamburg, July 18, 1803, and renewed at St. Petersburg, under the auspices of the Imperial Academy of that city, by the same Robertson and the Russian physicist, Saccharoff, June 30, 1804, that the magnetic force which directs the needle at the surface of the earth grew considerably weaker in proportion as they rose in the atmosphere. This fact, which confirmed the diminution of this same force that M. de Saussure supposed he had discovered in his celebrated journey to the Col du Géant, seemed to the principal members of the Institute, with good reason, to justify an especial experiment. This was confided to the physicists, Messrs. Biot and Gay-Lussac, both young, enterprising, and courageous. This last term may perhaps seem somewhat exaggerated to those who, in our day, have seen women, aping in their costumes winged butterflies, placed entirely outside of the car of the aerostat, rise from our public gardens, before the eyes of a wonder-struck crowd. But such would forget that now balloons are con structed with infinitely more care, and the means of safety have very much increased.

Our two physicists ascended from the garden of the Conservatoire des Arts et Metiers August 24, 1804, furnished with all the instruments necessary for investigation, but the small dimensions of their balloon did not allow them to exceed a height of 4,000 meters. At this elevation they endeavored, with the aid of the oscillations of a horizontal magnetic needle, to solve the problem which had been the chief object of their ascension, but the rotary motion of the balloon presented unforeseen and serious obstacles. They succeeded, however, in partly surmounting them, and they determined, in these aerial regions, the duration of five oscillations of the magnetic needle. It is known that this duration must increase when the magnetic force which brings back the needle to its natural position has decreased, and that this duration must be shorter, as the same directing force has increased. It is therefore a case entirely analogous to that of the oscillating pendulum, although the motion of the needle is performed in a horizontal direction. The consequences deduced from their experiments seem to me subject to difficulties, which I shall point out after giving an account of the ascension made a few days later by Gay-Lussac alone.

ASCENSION OF GAY-LUSSAC ALONE—CONSEQUENCES OF THE OBSERVATIONS MADE ON MAGNETISM AND TEMPERATURE—IMPORTANCE OF AERONAUTIC VOYAGES.

This ascension took place September 16, 1804, at forty minutes after nine in the morning. This time Gay-Lussac ascended to a height of 23,000 feet, 7,016 meters above the sea, the greatest well-authenticated height that man had then succeeded in attaining, and which, since that epoch, has been but once slightly exceeded by Messrs. Barrel and Bixio.

This second ascension has enriched physics with several important results, which I will endeavor to explain in a few words.

We find, for instance, that at the moment when Gay-Lussac's thermometer, at a height of 7,016 meters, indicated 9°.5 below the freezing point, that of the Observatory of Paris, in the shade, and with a northern exposure, stood at + 27°.75. Therefore 37° was the extent of the thermometrical scale to which Gay-Lussac found himself exposed during the interval from 10 o'clock in the morning till 3 in the afternoon. It was therefore no longer possible to attribute the perpetual snows existing on the summits of high mountains to any special action exerted by those rocky summits on the surrounding strata of air, as no considerable terrestrial elevation existed in the regions above which Gay-Lussac's balloon had successively passed.

Are these enormous variations of temperature connected in any way by a simple mathematical law with the changes of height?

By taking as exact the thermometrical observations, about which Gay-Lussac himself raises some doubts, on account of the rapidity of the ascensional motion of the balloon, and the time required by a thermometer to indicate exactly the temperature of the mediums into which it is immersed, we would arrive at this curious result, that the temperature would vary less for a given change of height near the earth than in the regions of the atmosphere of a mean elevation.

But I must remark that the ordinary manner of discussing aerostatic observations leads us into a vicious circle. The analytical formula, by means of which the successive heights of the balloon are calculated, absolutely supposes, in fact, an equal abatement of temperature in every region of the atmosphere for the same change of height. The observations of 1804, and those subsequently made, will only give results free from all objection when discussed according to the profound method for which we are indebted to our ingenious and illustrious associate M. Biot.

The difficulties might have been avoided if observers, furnished with theodolites, and distributed at proper distances, had determined trigonometrically by their combined observations the successive heights of the balloon. Scientists and academies desiring to enter anew upon the scientific study of the physical constitution of our atmosphere will certainly not fail to take my suggestions into serious consideration.

The hygrometer of de Saussure gave indications, during the ascension of Gay-Lussac, of an irregular movement; but taking into account, at the same time, the degrees indicated by this instrument and the temperature of the strata in which it was observed, our associate found that the amount of humidity contained in the air continued to diminish with extreme rapidity.

It was already known at the time of this memorable ascension that air in all latitudes, and at a height very slightly above the level of the sea, contained about the same proportions of oxygen and azote. This resulted with proof from the experiments of Cavendish, Macarty, Berthollet and Davy. It had also been ascertained by the analyses of Theodore de Saussure, of air brought from the Col du Géant, that at the height of that mountain the air contains the same proportions of oxygen as that of the plain below.

The eudiometrical analyses of Gay-Lussac, made with the greatest care, of air collected at a height of 6,636 meters, established the fact that the air of those high regions was not only composed of oxygen and nitrogen, like that at the surface of the earth, but, moreover, that it did not contain an atom of hydrogen.

It is not necessary to insist here upon the importance of these results; they showed the vagueness of the explanations given then by meteorologists of shooting-stars and other atmospheric phenomena.

The following extract from Gay-Lussac's own narrative gives some clew to a true explanation of the discomfort experienced by the most robust travelers in climbing elevated peaks, such as Mont Blanc:

"On reaching the highest point of my ascension, 7,016 meters above the mean level of the sea," said the courageous physicist, "my respiration was sensibly affected, but I was far from feeling yet a discomfort sufficient to induce me to descend. My pulse and respiration were very much accelerated; breathing very rapidly in air of extreme dryness, I ought not to have been surprised that my throat was so dry that it was impossible to swallow bread."

Let us now pass on to the experiment which was the chief object of the two aerostatic voyages, undertaken under the auspices of the first class of the Institute. The question was, as I have previously said, to assure themselves whether, as announced, the magnetic attraction exerted by the earth on a magnetic needle decreases very rapidly with the height. Gay-Lussac succeeded, in this second ascension, in counting, in a given time, twice as many oscillations as in the first. The results must, therefore, furnish much greater exactness. He found that a needle which at the surface of the earth required $42^s.2$ to make ten oscillations, at a height of 4.808 meters above Paris made the same number of oscillations in only $42^s.8$. The result was $42^s.5$ at 5,631 meters, and $41^s.7$ at 6,884 meters. These numbers do not give much regularity; it would have been necessary, as Gay-Lussac himself remarks, in order to deduce rigorous consequences, to combine them with the corresponding measurements of the inclination, which could not be effected.* Our friend, as M. Biot did, from the discussion of the numbers collected in the first ascension, drew from his observations the conclusion that magnetic attraction is constant at all accessible heights. This consequence was logical, at a period when it was not generally known that, in a given place and under given circumstances, the duration of the oscillations of a magnetic needle is influenced by its temperature, and that a decrement of the thermometer of 37° must produce the most remarkable changes. We see that owing to the imperfect state of the instruments, and of science in 1804, it was impossible to arrive at an exact solution of the problem in question. Moreover, it would be astonishing at the present time to hear that the problem had been solved.

No considerations of any nature would authorize throwing a veil over the gaps of science. This reflection especially concerns the works of men whose authority is incontestable and uncontested.

Gay-Lussac, after having finished all his investigations with the calmness and composure of a physicist seated in his laboratory, landed at forty-five minutes after three o'clock, between Rouen and Dieppe, forty leagues from Paris, near the hamlet of St. Gourgon, whose inhabitants executed with great readiness all the maneuvers directed by the aerial voyager in order that the car should avoid the shocks that would have placed the instruments in danger.

The dignity of this assembly and of the narrative should not, I think, prevent my relating a singular anecdote, for which I am indebted to my friend. Having reached a height of 7,000 meters Gay-Lussac was desirous to rise still higher, and for this purpose rid himself of every article not absolutely needed. Among these was a white wooden chair, which fell by chance into a bush near a young girl guarding some sheep. What was the astonishment of the shepherdess, as Florian might have said. The sky was pure, the balloon invisible. How explain the chair, if it came not from paradise? The only argument against this conjecture was the coarseness of the work; the workmen, said the skeptics, must be very unskillful above. The dispute was at this point when the journals, publishing the particulars of Gay-Lussac's voyage, put an end to it, and classed among natural effects what until then had seemed to them a miracle.

The ascensions of M. Biot and Gay-Lussac will live in the memory of men as the first which have been made with marked success for the solution of scientific questions.

The very remarkable meteorological phenomena of a fall of the ther-

* Gay-Lussac succeeded in observing the dip of the needle, only at a height of 4,000 metres. He found there, in round numbers, 30°. This result, supposing it to be exactly reported, differs immensely from the dip which takes place upon the earth.

mometer to 40° below freezing at a height of 7,049 meters, verified by M. Bixio and M. Barrel during an ascension, undertaken at their own expense, July 27, 1850, clearly prove that glorious discoveries are awaiting those who will follow in their footsteps, provided they have the necessary information and are furnished, as were these two physicists, with a collection of exact instruments. It is sincerely to be regretted that the ascensions, made almost every week, under circumstances more and more dangerous, and which, it may be painfully predicted, will end in some terrible catastrophe, have turned aside the friends of science from their projected voyages. I can imagine their scruples, but without sharing them. The spots on the sun, the mountains in the moon, the ring of Saturn and the belts of Jupiter have never ceased to be objects of investigation to astronomers, although now shown for ten centimes on the *terre-plein* of Pont-Neuf, at the foot of the column of the Place Vendome, and at different points of our boulevards. The public, now so discriminating and enlightened, would not confound those who daily expose their lives for lucre, with physicists, running the same risks to rob nature of some of its secrets.

ASSOCIATION OF GAY-LUSSAC WITH M. DE HUMBOLDT—WORK ON THE EUDIOMETER—TRAVELS IN ITALY AND GERMANY.

However slightly conversant with the literary history of the first half of this century, all have heard of the warm and profound friendship of M. de Humboldt for Gay-Lussac, and of the influence it exerted over the scientific career of the able chemist; but it is not so well known how it originated and was developed, and this deserves to be related.

Before starting on the memorable journey which has made America known to us under so many different aspects, M. de Humboldt prepared himself for it by diligent study. The object of one of his researches was the eudiometrical means in use to determine the constituent principles of air; this work, done in haste by an imperfect process, was somewhat inaccurate. Gay-Lussac perceived this and criticised the error with an alacrity that I would venture to condemn, if it were not rendered excusable by the author's youth. It is unnecessary to mention that Berthollet received M. de Humboldt on his return with the frank cordiality and well-bred politeness which characterized the illustrious chemist, and which is engraved in indelible characters on the minds and hearts of all who had the happiness of knowing him.

One day, M. de Humboldt remarked, among the company assembled in the salon of the country-seat of Arcueil, a tall young man of modest but dignified bearing. "This is," said some one to him, "Gay-Lussac, the physicst, who recently fearlessly ascended into the atmosphere to the greatest height yet reached by man, to solve important scientific questions." "This is," added Humboldt aside, "the author of the sharp criticisms on my eudiometrical work." But soon mastering the sentiment of resentment, naturally inspired by such a reflection on a high-spirited nature, he approached Gay-Lussac, and, after some complimentary remarks on his ascension, extended his hand and affectionately offered his friendship. It was, with due allowance, the *Soyons amis, Cinna!* (Let us be friends!) of the tragedy, but without the mortifying reflections which, as Voltaire relates, were made by the Maréchal de la Feuillade, after having heard them for the first time. "Ah! Auguste, how you do spoil the *Soyons amis, Cinna!*" Such was the origin of an attachment that was never interrupted, and that soon bore the happiest fruits. We see in fact, immediately afterward, the two new friends executing conjointly an important eudiometrical work.

This work, read at the Academy of Sciences, the 1st Pluviôse, year XIII, had for its principal object an estimate of the exactness that could be arrived at in an analysis of air with Volta's eudiometer; but the authors at the same time touched upon a multitude of questions relating to the chemistry and physics of the earth, throwing great light upon them and making very ingenious conjectures. It is in this memoir that the remark is found (which has since received, at the hands of Gay-Lussac, developments so important) that oxygen and hydrogen, considered in volumes, unite to form water, in the definite proportion of 100 of oxygen and 200 of hydrogen.

Our scientific annals present a large number of memoirs published under the name of combined authors. This kind of association, much less common abroad, is not without its drawbacks. If we except the very rare case, of which however I could cite instances, where the part of each collaborator was clearly defined in the joint editorship, the public is obstinate in refusing an equal share to both associates. It frequently dismisses, as caprice dictates, the formulas, *we thought, we imagined*, on the very plausible pretext that the same idea cannot present itself at the same time to the minds of both associates. It refuses to one of them all intellectual initiative and reduces his share to the mechanical execution of the experiments.

These inconveniences of publishing in common, almost inherent in human nature, disappear when, by way of exception, one of the associates resolves not to indulge the public in its prejudiced and often malicious surmises, by unhesitatingly disclaiming any part belonging to the other. It was the good fortune of Gay-Lussac to meet with such a collaborator. Here is, in fact, what I read in a note by M. de Humboldt: "Let us insist upon the remark contained in this memoir, that 100 parts in volume of oxygen require 200 parts in volume of hydrogen gas for saturation. Berzelius has already reminded us that this phenomenon is the germ of what was discovered later about definite proportions, but the fact of complete saturation is due to the sagacity of Gay-Lussac alone. I co-operated in this part of the experiments, but he alone foresaw the importance of the result to the theory." A declaration so frank and loyal from this illustrious and venerable academician will astonish no one.

We will refer farther on to this very remarkable portion of Gay-Lussac's works. Gay-Lussac, assistant professor of the Fourcroy course, obtained, through the friendly intervention of Berthollet, leave for a year to accompany M. de Humboldt in his travels through Italy and Germany. The two friends, before leaving Paris, provided themselves with meteorological instruments, and especially apparatus suitable for determining the inclination of the magnetic needle and the intensity of the variable force which directs the magnetic needle in different latitudes. They left Paris March 12, 1805, and experimented with their instruments at Lyons, Chambéry, St. Jean de Maurienne, St. Michel, Lanslebourg, and Mont Cenis, &c. I will return elsewhere to the magnetic results of this journey in a memoir of our colleague inserted in the collection of the Society of Arcueil. Gay-Lussac had imbibed in his youth the meteorological theories of Deluc, some of which had almost captivated him, but in his passage over the Alps his ideas were entirely modified. He felt the need, for example, of having recourse to the action of ascending atmospheric currents to explain a large number of curious phenomena.

Nothing enlightens and enlarges the ideas more, with regard to natural phenomena, than traveling in mountainous regions, especially when so fortunate as to enjoy the society of as cultivated, ingenious, and experienced an observer as M. de Humboldt.

Gay-Lussac and his illustrious fellow-traveler, after visiting Genoa, went to Rome, where they arrived July 5, 1805, and alighted at the palace Tommati alla Trinita di Monte, the residence of William de Humboldt, chargé d'affaires of Prussia.

In the society of him who has so eloquently described it, the grand scenery of the Alpine regions could not fail to excite genuine enthusiasm in Gay-Lussac's soul. The sight of the immortal monuments of architecture, of the painting and sculpture with which Rome abounds, joined to the learned conversations of the Rauches, Thorwaldsens, &c., habitués of the Tommati Palace, awakened in the youthful traveler a taste for the fine arts, which until then had been latent. Finally he enjoyed the advantage of admiring the fascination of talent; for Madame de Staël then held every salon of the Eternal City under the spell of her eloquent and spirituel conversational powers. Gay-Lussac's sojourn in Rome was not without fruit to the science of chemistry. Thanks to the courtesy of Morrichini in placing a chemical laboratory at the disposal of the young traveler, he was able to announce, July 7, that fluoric acid existed with phosphoric acid in the bones of fishes. July 9, he finished the analysis of the alum rock of the Tolfa.

July 15, 1805, Messrs. de Humboldt and Gay-Lussac left Rome and started for Naples, accompanied by M. Léopold de Buch, who, though still young, had already distinguished himself by very valuable geological researches. Vesuvius, in a state of rest at that period, suddenly exhibited the most magnificent and terrible evolutions, (as if to celebrate the welcome of the three illustrious observers;) eruptions of dust, torrents of lava, electrical phenomena, nothing was wanting.

Finally Gay-Lussac had the *good fortune*, (the expression is not mine; I borrow it from one of the fellow-travelers of the learned chemist)—he had the good fortune of being witness of one of the most frightful earthquakes ever experienced at Naples.

Gay-Lussac eagerly seized this opportunity of coping with the problem which, since Empedocles, had defied the sagacity of observers. We will soon give an account of the results collected by our friend in the six ascensions of Vesuvius which followed each other in quick succession.

The time not devoted by Gay-Lussac to the study of the burning volcano was employed in examining the collections of natural history, and especially of former volcanic eruptions, which are found in great numbers in Naples; our travelers had much reason to be gratified at the kind attentions and exquisite politeness of the Duke de la Torre and Colonel Pole; but such was not their experience with Dr. Thompson. When they presented themselves, accompanied by a Neapolitan scientist, to study his museum, he addressed them in these outrageous words: "Separate yourselves, gentlemen; I can keep my eyes on two, but not upon four." One feels tempted to ask from what society of lazzaroni had Dr. Thompson borrowed sentiments so low and language so indecent; but all is explained when we learn that Thompson was the physician, friend, and confidential agent of General Acton, the instigator of the political assassinations which defiled Naples at the close of the last century.

In his expeditions around Naples, by land and water, M. Gay-Lussac corrected some erroneous ideas, then generally entertained. He found, for example, that the air confined in sea-water contained, instead of 21 parts of oxygen, as ordinary air does, above 30 parts of oxygen for 100. He visited Monte Nuovo and Epomeo with M. de Buch. On seeing Monte Nuovo, Gay-Lussac fully adopted the opinion that M. de Buch was then beginning to disseminate in the scientific world, according to which mountains may suddenly spring out of the earth by means of upheavals.

Epomeo seemed to them to have the characteristics of an abortive volcano, without fire, or smoke, or crater of any kind.

After having finished their labors in Naples, our travelers returned to Rome, where they remained but a short time. On the 17th of September, 1805, Messrs. de Humboldt, de Buch, and Gay-Lussac quitted Rome to repair to Florence. They took the mountain road, in order to visit the celebrated baths of Nocera, near which Popes Clement XII and Benoit XIII had erected some real palaces, with all the necessary appliances for invalids, who, from June until September, brought plenty into the surrounding country.

There an important problem was presented. Morrichini had found, by chemical analysis, that air obtained from these waters contained 40 per cent. of oxygen—that is to say, about double the proportion of the same gas in atmospheric air, which seemed incredible. Gay-Lussac discovered in reality that the air procured from the water of the baths contained 30 per cent. of oxygen, as spring-water usually does. The salutary effects of the waters must therefore be sought elsewhere, as they were found so remarkably pure, no re-agent disturbed them. Is it this purity that renders them so efficacious?

In mythological times, heroes, celebrated by the Greek poets, roamed desert countries to battle with the brigands and wild beasts they sheltered. Our travelers, as we see, seemed in their turn to have assumed the mission of destroying by the way errors and prejudices, which often make more victims than the monsters of antiquity exterminated by Hercules, Theseus, Pirithöus, &c.

These scientists reached Florence September 22, and Fabbroni, superintendent of the museum, received them with the greatest distinction. He did the honors of the rich collection, at the head of which the Tuscan government had placed him, in a manner to prove how worthy he was of the confidence he enjoyed. Gay-Lussac took great delight in his society; he especially admired the knowledge and ability displayed by Fabbroni in pointing out the merits of the productions of Michel Angelo and of the illustrious painters and sculptors, successors of this great man. He was not so much charmed with the learned director when, on asking him the value of the inclination of the magnetic needle, Fabbroni replied that the beautiful instruments which adorned the laboratory of the grand duke had not been used for fear of tarnishing the metal. He did not enjoy either the reunions where Madame Fabbroni, celebrated for the elegance and beauty of her poetry, the center of a circle composed of the most distinguished society of Florence, was in the habit of directing against every topic in succession flashes of wit to which the individual addressed was obliged to reply at once and in his best manner. These theatrical customs have happily disappeared from among our neighbors to give place to conversations where each freely takes the part which suits his position and even his timidity.

On the way from Florence to Bologna, where our three travelers arrived safely September 28, they stopped at Piétra-Mala to study the perpetual flames previously examined by Volta.

At Bologna Gay-Lussac visited Count Zambeccari, who had lost six fingers by sliding along a rope to escape a catastrophe which was threatening him, the montgolfiérè in which he had ascended into the air having taken fire; his sufferings did not prevent his discussing with Gay-Lussac a plan he had formed, and which, at a later period, was to cost him his life—that of ascending again—but this time with a balloon filled with hydrogen gas which he could heat more or less at will, by means of a circle of lamps with a double draught of air. It will be seen that the unfortunate aerial traveler was contriving in his new scheme a method by which he would substitute the risks of explosion for those of the conflagration of his first attempt. Our travelers remained but a short time in Bologna, whose university had then singularly declined from its ancient reputation. The professor of chemistry of this university, M. Pellegrini Savigny, had left no very favorable impression upon Gay-Lussac's mind; our colleague accused him of having degraded the science by inserting in his *Traité de Chimie* (Treatise upon Chemistry) methods of his own invention for preparing good sherbets and excellent soups for every day in the year.

Did not our friend indulge in some exaggeration in classing the subjects alluded to in the treatise of M. Pellegrini among those which a scientist, who has any self-respect, should abandon to professional charlatans? I will venture to say, in spite of my profound deference for Gay-Lussac's opinions, that he who should succeed in reducing to uniform and precise rules the preparation of our food, especially that of the poorer classes, would solve an important hygienic question. I am persuaded that some day posterity will manifest astonishment on learning that in the middle of the nineteenth century the alimentary regimen of the masses was abandoned to empirics, of both sexes, without education or intelligence.

Byron relates in his memoirs, that during Sir Humphry Davy's sojourn in Ravenna, a fashionable woman expressed the desire that the illustrious chemist should prepare for her a pomade to darken her eyebrows and make them grow. I would unreservedly share the contemptuous disdain with which our young friend would undoubtedly have received such a proposition as this. But there is, it seems to me, a wide difference between the pomade for the fashionable woman and formulas for improving the food of the people, and even that intended to satisfy the sensuality of the rich.

Messrs. de Humboldt, de Buch, and Gay-Lussac reached Milan October 1. Volta was then in that city, but they had great difficulty in finding him.

The civil and military administration of Milan, which would not have hesitated a moment if asked the address of a simple Hungarian or Croatian sublieutenant, of a contractor, or of any titled personage whatsoever, seemed utterly unmindful of Volta, that great man, the glory of Lombardy; whose name will be uttered with respect and admiration when the breath of time will have swept away even the slightest recollection of generations of his contemporaries.

Let us turn aside from these several anomalies, a thousand instances of which it would be easy to enumerate, and resume our narrative.

Our three young travelers learned in Milan that the scientific world was alive with the rumor of a pretended discovery by M. Configliachi. According to the Italian chemist, water was composed of muriatic acid and soda, elements that the battery decomposed without difficulty. Volta, consulted by our three travelers as to the merit of the observation, replied, "I have seen the experiment, but I do not believe in it."

It was in these terms the immortal physicist expressed the caution which should meet all extraordinary facts similar to the pretended phenomenon by which his pupil Configliachi hoped to attain a great reputation. The remark is peculiarly applicable to facts ascertained by instruments of a delicacy so extreme as to be influenced by the presence, breath, and emanations from the body of the observer. The Voltaic dictum, "I have seen it, but do not believe in it," might have been applied on some recent occasions; it would have saved science some retrograde steps, and certain authors unqualified ridicule.

On the 14th and 15th of October our travelers crossed Saint Gothard. Gay-Lussac was denied the enjoyment of a spectacle from which he had anticipated much pleasure and instruction, a thick fog concealing from view even the nearest objects for a whole day. He compensated himself for this disappointment by a minute study of General Pfiffer's fine relief of Switzerland.

At Gottingen, November 4, the great naturalist Blumenbach, at that time full of life and activity, cordially extended the honors of the university to our young countryman.

On the 16th of the same month Gay-Lussac arrived at Berlin, where he remained all winter under the roof of M. de Humboldt, kindly welcomed and appreciated by all the distinguished men of the city; he passed much of his time in the society of Klaproth, the chemist, and Erman, the physicist.

Gay-Lussac quitted Berlin in the spring of 1806. He very suddenly determined to leave on learning that the death of Brisson left a vacancy in the Institute, and that he might be chosen to fill the place of the aged physicist.

In examining now the works of Gay-Lussac's contemporaries who, in 1806, were in a position to contend with him for the vacancy in the Academy of Sciences, it seems astonishing that his presence should have been indispensable to his success; but it is that we forget that at the end of the eighteenth century and beginning of the nineteenth no one was a real physicist unless possessing a valuable collection of instruments well polished, well varnished, and arranged in glass cases. It was not without trouble that Gay-Lussac, who owned only a few instruments of research, succeeded in overcoming such prejudices. Let us preserve these memories for the consolation of those who have experienced, or may in the future experience, disappointments in academic elections.

GAY-LUSSAC'S RESEARCHES ON DILATATIONS.

A short time before Gay-Lussac, now a member of the institute, had begun to apply his experimental talent to the study of the changes of the elastic force of gases with the temperature, and the formation and diffusion of vapors, the same field of research had been explored in England by an equally clever man, Dalton, numbered by the academy among its eight foreign members. Dalton, although his genius was not unknown to his countrymen, occupied in the small town of Kendal the very humble and somewhat unprofitable position of private tutor of mathematics, and had only at his command for his experiments imperfect instruments. There would then have been no impropriety in subjecting his results to careful verifications. Gay-Lussac was not acquainted with the works of the illustrious English physicist, as there was no mention of them in the full and instructive account of the experiments made by the physicists who had preceded him. Dalton had found that air expands 0.392 in the interval between 0° and 100° of the centigrade thermometer. Already, previously, as I had ascertained from a printed document, Volta had given for this expansion 0.38. Finally, in 1807, Gay-Lussac found it to be 0.375. This number was generally adopted up to a recent period, and employed by all the physicists of Europe.

According to the late determinations of Rudberg, and Messrs. Magnus and Regnault, there was an error of about $1\frac{1}{38}$ in the value of the dilatation of air given by Gay-Lussac; our colleague never objected to the number 0.3665 substituted by our fellow-laborer, M. Regnault, for the number 0.375 which he had given. But what could be the real cause of this difference? Gay-Lussac has never given any public explanation of this disagreement. Not anticipating the catastrophe which so suddenly removed him from us, I was guilty of the fault of not interrogating him directly upon this subject.

It would not be uninteresting, however, to investigate how so careful a physicist could allow himself to be drawn into such an error.

A German professor, celebrated for the importance of his discoveries, M. Chladni, visited Paris some years since. Smarting under the difficulties which he had encountered in all his investigations, he said in an impressive tone and petulant manner, never to be forgotten, for in their exaggeration they almost bordered upon the ridiculous: "When you desire to lift the smallest corner of the veil which envelopes nature, she invariably exclaims "No! No! No!" M. Chladni might have added that at the moment when it seems about to yield, it surrounds the observer with snares into which the most skillful fall without suspecting it.

What could be the causes of error in the experiments of Volta, Dalton, and Gay-Lussac that these illustrious physicists had not perceived? I have heard it said that the drop of mercury designed to intercept communication between the vessel in which the air was expanded and the external atmosphere, leaving a slight space and giving passage to a portion of the dilated air, was not displaced as much as it would have been without that; but this cause would evidently have given too small a co-efficient, and it was in the opposite direction, according to the recent observations, that the number upon which Gay-Lussac had decided was in fault. It was much more probable that the interior of the sides of the vessel in which the celebrated academician operated were not sufficiently dry; that the hygrometric vapor, adhering to the glass at low temperatures, evaporated when the apparatus was submitted to high temperatures; that it increased, therefore, without any means of detecting it, the volume of the elastic fluid upon which they desired to operate. I point out this cause with the more confidence that it is now established that the glasses, according to their composition, and even according to their degree of annealing, are diversely hygrometrical; so that the degree of heat which would cause complete desiccation in one of these glasses would be insufficient when operating in another apparatus. Gay-Lussac had perfectly understood the effect that hygrometric vapor should produce, and he attributed to this cause the errors of his predecessors. Therefore, it was in following with a little more precaution in the paths traced by our friend that this error of $\frac{1}{36}$ imputed to him was discovered, an error which could do no real injury to the just and legitimate reputation for exactness which this learned physicist had acquired and which subsequent works so fully justified.

When Gay-Lussac was occupied with the numerical determination of the dilatation of elastic fluids by heat, our most skillful physicists thought that different gases have different co-efficients. Witness, for example, what Monge says, which I quote from his memoir on the composition of water: "Elastic fluids are not all equally dilatable by heat." Gay-Lussac found within the limits to which his experiments were confined that this was an error. Since then there has been a return to the first opinion. Indeed, it is almost a consequence of the fact verified by Davy, and especially by our colleague, M. Faraday, that gaseous bodies can be liquefied, and under pressures different for each one of them.

SOCIETY OF ARCUEIL—MEMOIRS ON MAGNETISM—LAWS OF GASEOUS COMBINATIONS—CATHETOMETER.

In 1807 Berthollet formed a private scientific society, composed of a small number of individuals and called the Society of Arcueil, after the commune, in the neighborhood of Paris, in which the country-seat of this illustrious chemist was situated. Gay-Lussac, as may be readily imagined, was one of the first members of the new society. Before proceeding further, let us say a few words about the criticisms to which this kind of dismemberment of the first class of the institute formerly gave rise. It was eminently flattering to young *débutants* in science to have as chief judges and counselors in their labors men of European celebrity, such as Laplace, Berthollet, Humboldt, &c.; but could it be asserted that preconceived ideas to which the cleverest minds more readily abandon themselves in an intimate reunion, so to speak, than before a promiscuous public, had not a tendency to arrest the spontaneity of genius and repress its researches below a conventional level? On the other side, might not the desire to give evidence of fertility of mind, in the presence of the most famous scientists, sometimes lead enthusiastic spirits to venture upon bold theories?

Whatever may be thought of these doubts, which I mention with great hesitation, the independent and sober judgment of Gay-Lussac would have placed him beyond influences which would not have been called into play except under cover of eminent merit or fertility and of imagination. His publications in the three volumes of the memoirs of the Society of Arcueil deserve in every respect, from their variety, their novelty, and also their exactness, to occupy the most distinguished place in an impartial history of the sciences.

The first volume of the collection, published by the Society of Arcueil, begins by a memoir in which Gay-Lussac has combined the results of all the magnetic observations made in conjunction with M. de Humboldt, during the journey through France, Italy, and Germany, of which we have already spoken at length. This branch of the science has for some years been making very considerable progress, and yet we can confidently recommend to physicists those pages on which Gay-Lussac has examined all the causes of error which may affect the measurements of inclination and intensity, and the precautions to be taken to avoid them. We know now that the horizontal force which directs the magnetic needle is subject to a diurnal variation which depends in part, but only in part, upon a corresponding variation in the inclination. We have likewise learned that in a given place and at a given time the duration of the oscillations of a needle depends upon its temperature. It would therefore be now necessary, if a magnetic voyage were undertaken, to take into account all of these disturbing causes; but, and we can say it without flattery, at the period when it was published, the work of Messrs. de Humboldt and Gay-Lassac was a model.

If we cast our eyes over the second volume of the Memoirs of Arcueil, we will find there, among other clever works of interest—a *Memoire sur la Combinaison des Substances Gazeuses entre elles*, "Memoir on the combination of gaseous bodies with each other." This memoir contains results so remarkable, so important, that they are habitually called the laws of Gay-Lussac. It would now be very difficult for me to give a detailed and perfectly accurate account of the atomic theory. This sketch should, I think, go back as far as Higgins, an Irish chemist, whose work, published in 1789, is only known to me through very short quotations by Humphry Davy. Then come the researches of Dalton in 1802. It is a matter of certainty that the law of volumes was demonstrated experimentally by our associate in 1808, without any knowledge on his part of the first more or less systematic investigations of his predecessors.

The laws to which we have alluded may be announced in these terms: Gases, in acting upon each other, combine in volume in the simplest ratios; such as 1 to 1, 1 to 2, or 2 to 3. Not only do they only unite in these proportions, but again, the apparent contraction of volume which sometimes occurs by the combination bears also a simple ratio to the volume of one of the combined gases. Gay-Lussac, later, had the boldness to deduce from his laws the density of the vapors of several solid bodies, such as carbon, mercury, and iodine, integral parts of certain gaseous combinations. This boldness, as proved by subsequent experiments, was crowned with perfect success.

Recently it was thought possible to deduce from the unequal dilatation of different gases by heat the proof that the law of volumes is not mathematically exact. Let us suppose, the learned critics say implicitly, that two gases combine in equal volume and at a fixed temperature—for example, that of 20° centigrade—and that the combination is made molecule by molecule let us carry to 40° the temperature of the two gases. If at 20° equal volumes contain the same number of elementary particles, such would not be the case at 40°. There will then be unequal volumes which will enter into combination, supposing that the union must always be effected molecule by molecule. It will be seen that the criticism implies the absolute truth of the atomic theory of combination, which, by the way, may seem not so firmly established as the law of Gay-Lussac. Besides, would not that have been a very singular coincidence which should have led our colleague to operate precisely at the temperatures at which this law should be rigidly exact?

Let us remark, in point of fact, that in the study of nature it has rarely happened that experiment has led, through some light deviations, to simple laws, unless these laws have become the definite regulators of the phenomena. The system of the earth offers a striking example of this truth. The laws of the elliptical movement of the planets are only exact by disregarding the irregularities known under the name of perturbations, and which place each planet sometimes in advance, sometimes behind the position assigned to it by the immortal laws of Kepler.

If it is ever established by direct experiments that the principles laid down by Gay-Lussac are not confirmed when the temperatures come to vary, it will be the time to investigate whether there be not a natural cause to which these perturbations may be attributed.

In the limited compass assigned me I could only present simple doubts on the nice question I have ventured to broach; at all events, the assimilation which they have suggested to me seems of a nature to satisfy the most enthusiastic partisans of the scientific glory of Gay-Lussac. When Laplace, looking at capillary phenomena in a new light, desired to compare the results of his skillful calculations with those of observation, and when he wished the subject to have the final seal of experiment, he applied to Gay-Lussac. The latter fully responded to the confidence of the immortal geometer. I should add that the instrument which he invented is of small dimensions—the same, under the name of cathetometer, now so generally in use among physicists. I leave to those who consider they have the right, the responsibility of laying claim to priority in the use of the word cathetometer now generally adopted; but the instrument in principle and even in form will not the less remain one of the valuable inventions with which our colleague has endowed science.

WORKS ACCOMPLISHED BY MEANS OF THE BATTERY OF THE POLYTECHNIC SCHOOL.

We have now reached the period when, treading in the path so successfully opened by Nicholson and Carlisle and followed by Berzelius and Hisinger, Sir Humphry Davy succeeded, by means of the battery, in transforming potash and soda into metals which could be kneaded with the fingers, like wax; which float on the surface of water, because lighter than it, and which ignite spontaneously in this liquid, diffusing the brightest light.

The announcement of this brilliant discovery, at the close of 1807, created a profound sensation in the scientific world. The Emperor Napoleon took part in it, and placed at the disposal of the Polytechnic School the fund necessary for the erection of a colossal battery. While this powerful instrument was being constructed, Messrs. Gay-Lussac and Thénard, to whom it was to be confided, conceiving that ordinary affinity, well directed, would suffice for the production of potassium and sodium, attempted various very dangerous experiments, and succeeded beyond their expectations. Their discovery was published March 7, 1808. From this time the two new metals, which were only obtained in very small quantities by the battery, could be produced in great abundance, and thus became the usual instrument of chemical analysis.

As may be easily imagined our two celebrated countrymen did not allow the means of investigation they had just so skillfully prepared to remain idle in their hands. They placed the potassium and sodium in contact with nearly all known chemical substances, and noticed, during the experiment, the reactions most fertile in theoretical consequences. We will content ourselves by citing here the decomposition of the acid formerly known as boracic, and the discovery of its radical, called by its discoverers *boron*. We must likewise rank very high in their investigations the very difficult and varied experiments by which they determined the actions exerted by the two new metals on ammonia; the results of their work on fluoric acid, now called fluohydric, and the discovery of the new gas which they named fluoboric. Following the chain of their researches, the two illustrious chemists were led to attempt the analysis of the substance then denominated oxygenated muriatic acid; they made known the results of their numerous experiments February 27, 1809. Their communication finished with this paragraph, which I transcribe literally: "According to the facts reported in this memoir, it might be supposed that this gas (oxygenated muriatic acid gas) is a simple body. The phenomena which it presents are sufficiently well explained in this hypothesis; we do not seek, however, to vindicate it, because it seems to us that they are explained still better by regarding oxygenated muriatic acid gas as a compound body." They made by this declaration a large concession in favor of the prevailing opinions of the Society of Arcueil ; to those supported with great warmth by Laplace and Berthollet. Sir Humphry Davy, who was in no wise constrained by personal considerations, maintained that the first interpretation alone was admissible; he regarded oxygenated muriatic acid as a simple body, that Amperè proposed to call *chlorine;* common muriatic acid became then the combination of this radical with hydrogen, under the name of hydrochloric, or chlorohydric acid. This manner of interpreting facts is now generally adopted.

It is seen by this example that there are cases where the counsels of genius, when they assume the imperious character that counsels should never have, may sometimes lead the soundest minds astray from truth.

When the colossal battery constructed with the funds granted the Polytechnic School by Napoleon was finished, Messrs. Gay-Lussac and Thénard were eager to study its effects, but less energy was shown than was expected. So after various trials, without striking results the two illustrious chemists confined themselves to laying down general principles on the mode of action of these apparatus when they exceed the usual dimensions. We find in their work a chapter in which they examined the different causes which create a variation in the energy of the galvanic battery, in which they give the means of measuring its effects, and in which they study the influence exerted by the liquid contained in the troughs, according to its nature and the variations of intensity which may depend upon the number and surface of the plates employed.

ANALYSIS OF ORGANIC MATTER.

The analysis of animal and vegetable substances for some years has received immense developments and led to the most important results. This progress of the science is chiefly due to a method invented by Gay-Lussac to effect organic analyses, and which has been adopted by all chemists. Our colleague burned the substance to be analyzed with the binoxide of copper. This process was a great improvement upon the one he used with his associate and friend M. Thénard, in which combustion was effected by means of oxymuriate of potash, now known as chlorate of potash.

RESEARCHES ON IODINE.

M. Courtois, a manufacturer of saltpeter in Paris, discovered, about the middle of 1811, in the ashes of varec a solid substance which corroded his boilers, and which since, at the suggestion of Gay-Lussac, has been called *iodine*, from the extremely remarkable violet color of its vapor. M. Courtois sent samples of this substance soon after its discovery to Messrs. Desormes and Clément, who made it the subject of experiment. M. Clément did not make public M. Courtois's discovery, and the results he had obtained conjointly with M. Desormes, until the meeting of the first class of the institute, December 6, 1813. Sir Humphry Davy, who, on account of his scientific genius, had obtained from the Emperor especial permission to pass through France, was then in Paris.

He received from M. Clément, a short time after his arrival, numerous samples of the mysterious substance. M. Gay-Lussac learned this, and saw at a glance what mortifying criticisms affecting the honor of our experimentalists and academies might arise from resigning the priority, the result of chance and thoughtlessness, to the investigations of a foreign chemist. He went immediately to rue du Regardà, to the poor workman, obtained a small amount of the matter discovered by him, set himself to the task, and produced in a few days a work equally remarkable for the variety, the importance, and the novelty of the results. The iodine, under the searching eye of our colleague, became a simple body, furnishing a peculiar acid by combining with hydrogen, and a second acid by uniting with oxygen. The first of these acids proved, by a new example, that oxygen was not the only acidifying principle, as was believed for a long time. This work of Gay-Lussac upon iodine was subsequently completed; and there are found in a very long and beautiful memoir, read August 1, 1814, and published among those of the academy, the varied results of the investigations of our colleague.

Every chemist who has read this work admires in it the fertility of the author in varying experiments, and the soundness of judgment which always guides him when necessary to interpret them and draw from them general consequences. In several chapters of this very remarkable work the author dwells especially upon the analogy which he establishes between chlorine, iodine, and sulphur, which throws great light upon several branches of the science then involved in obscurity.

DISCOVERY OF CYANOGEN.

Prussian blue, a substance known to manufacturers and painters, had been the subject of the researches of a large number of scientists, among whom we will chiefly cite the academician Macquer, Guyton de Morveau, Bergman, Scheele, Berthollet, Proust, and M. Porrett.

Guy-Lussac, in his turn, entered the lists. His results are recorded in a memoir which was read before the first class of the Institute September 18, 1815. From this moment everything doubtful became a certainty; light succeeded obscurity. This memoir, one of the most beautiful of which science can boast, revealed a multitude of new facts of immense interest to chemical theories. Those who will read it with care will see at the cost of what fatigue, with what precautions, what sobriety in the deductions, what soundness of judgment, an observer succeeds in avoiding false steps, and bequeathing to his successors a definitive work; I mean a work which subsequent investigations will not essentially modify.

In that admirable memoir, the author first gives an exact analysis of the acid which enters into the composition of Prussian blue, and which was called by Guyton de Morveau prussic acid, but which was never obtained, until the work of our friend, in a state of purity, but mixed only with water. He then showed how he succeeded in separating the radical from prussic acid, which has since been denominated cyanogen. He established the fact that cyanogen is a compound of azote and carbon; that prussic acid is definitively formed from hydrogen and this radical; and that it should take the name of hydrocyanic acid, for which chemists now often substitute that of cyanhydric acid. He points out with the greatest care its reactions on a great number of substances, simple or compound, solid or gaseous. He makes known the combination of cyanogen with chlorine, which should naturally bear the name of chloro-cyanic acid. In brief, in this work Gay-Lussac filled a gap in chemistry by showing that there exists a combination of azote and carbon. He proved that cyanogen, although a compound, plays the part of a simple body in its combinations with hydrogen and metals, which, at the period when our colleague wrote, was the sole example in the science. I have said that, to establish results so grand, Gay-Lussac displayed indefatigable perseverance. If proof of it is wanted, I will mention, for instance, that, wishing to know what modifications electricity could produce in a mixture of two gases, he passed into it at least fifty thousand sparks.

We read with great regret, in the memoir of our colleague, the following paragraph: "I had indulged the hope, in devoting myself to these researches, of being able to throw some light on all the combinations of hydrocyanic acid; but the duties I have to perform have forced me to interrupt them before they had reached the degree of perfection to which I expected to bring them." What were these duties which, in 1815, hindered Gay-Lussac from completing this work of genius? It was—and I mention it with regret—the necessity of providing for his family, by giving public lectures almost daily, which consumed the time our friend had wished to devote more usefully to the advancement of science.

Cyanogen, one of the constituent principles of Prussian blue, furnishes, by combining with hydrogen, a poison so subtile that a celebrated physiologist, the first to use it in experiments on living animals, exclaimed, on seeing its effects, "Henceforth one may believe all that antiquity has said of Locusta." The same learned academician has proved by his experiments that in the poisoned animals no lesion in the organs essential to life is seen.

This action of the liquid obtained for the first time by Gay-Lussac will appear the more mysterious from the fact that it is produced by a substance composed of azote, one of the constituent principles of atmospheric air, of hydrogen, one of the constituent principles of water, and carbon, whose innocuousness is proverbial. One more reflection, and I have done with this article. Chemists never fail, when they discover a new product, to describe its taste. Who does not think with horror that if he had not departed from the usual custom, if he had placed one single drop of this liquid on his tongue, our friend would have fallen instantaneously, as if struck by a thunderbolt. The odor of bitter almonds which is exhaled, it is said, by the dead bodies of animals that have perished from the effects of hydrocyanic acid, would then have given no clue to the cause of this national catastrophe.

SIPHON BAROMETER—MANNER IN WHICH CLOUDS ARE SUSPENDED—STORM-CLOUDS—DIFFUSION OF GASES AND VAPORS—CENTRAL HEAT OF THE GLOBE.

Gay-Lussac published, in 1816, the description of a portable siphon barometer, now so widely spread, especially since the improvements made in it by the artist Bunten.

This is not the only service rendered to meteorology by our friend. In a note inserted, in 1822, in the twenty-first volume of the *Annales de Chimie et de Physique*, (Annals of Chemistry and Physics,) he has explained his views on the manner in which clouds are suspended. On looking at the ascensional motion that the ascending atmospheric current gives to soap-bubbles, evidently heavier than the air, he thought he might attribute the suspension of vesicular molecules to this same current, at much more considerable elevations.

Before this epoch, in 1818, in a letter addressed to M. de Humboldt, Gay-Lussac had investigated the causes of the formation of storm-clouds. According to him, the electricity constantly diffused in the air suffices to explain the phenomena presented by this kind of cloud. When the storm-clouds are of great density, they possess the properties of solid bodies; the electricity originally disseminated in their masses rises to the surface where it has considerable tension, by virtue of which it can overcome, at times, the pressure of the air and dart forth in long flashes, either from one cloud to another, or over the surface of the earth. It will be seen how greatly these views differ from those of Volta, the master of everything connected with electricity. Whatever be the opinion pronounced upon the rival theories, it must be acknowledged that in the discussion of what Gay-Lussac calls his conjectures, he has shown himself a very skillful logician and perfectly familiar with the most subtile properties of the electric principle.

Among the researches of our friend, designed to throw light upon the nicest points of meteorology, we must also mention those which concern vaporization and the dissemination of vapors, either on empty spaces or in spaces containing aeriform fluids.

I perceive that I shall scarcely be able to say even a few words about Gay-Lussac's views with regard to volcanic phenomena. These opinions were published in 1823, under the title of *Réflexions*, in a memoir inserted in the twenty-second volume of the *Annales de Chimie et de Physique*. The author does not believe that the central heat of the earth, if that heat exist, contributes at all to the production of volcanic phenomena. These phenomena, according to him, are owing to the action of water, probably sea-water, on combustible substances. According to this hypothesis, the torrents of gaseous matter which issue from the craters of volcanoes should contain a great deal of hydrogen and hydrochloric acid. The manner in which the author explains the absence of hydrogen in these aeriform emanations, and the processes which he points out to such men as Montecelli, Cavelli, and other scientific observers, suitably placed to ascertain the existence of hydrochloric acid, must be sought in the original memoir. I do not think that this memoir, in spite of its ingenuity, has solved the so much controverted question of volcanic phenomena. But I will in this case simply imitate the reserve of Gay-Lussac, who modestly said in beginning his memoir, "I do not possess the extent of information (in geology) required to treat such a subject. I shall merely skim lightly over its surface."

SERVICES RENDERED TO THE INDUSTRIES BY GAY-LUSSAC—ALCOHOLMETER—ALKALIMETER—MANUFACTURE OF SULPHURIC ACID—ASSAY OF GOLD AND SILVER BULLION.

According to the logical and unavoidable consequences deduced from the language of certain biographers, whose merits, in other respects, it gives me pleasure to acknowledge, the young man who devotes himself to science, particularly when brilliant success has marked his first steps, surrenders by so doing his personal freedom. In fact, they not only sometimes examine what those whose history they are writing have done, but claim to be able to determine what they should have done, at a period, too, when for want of inspiration they have felt, for the sake of their dignity and fame, the need of rest. In this examination they disregard the fatigue induced by age, the infirmities resulting from it, and family obligations, all as sacred to the man whose life is given up to study as to any other citizen.

Gay-Lussac has not escaped the consequences of this somewhat censurable manner of criticising. It has pleased some to divide the career of our colleague into two distinct phases: the first devoted to the speculative study of natural phenomena, the second entirely confined to the applications from which he was to realize substantial benefits.

In this second phase, which they claim fades into insignificance, if it is not diminished in importance by comparison with the first, Gay-Lussac, enjoying the favor of the government, was selected in succession to aid by his scientific knowledge in the manufacture of gunpowder; to act as adviser in the administration of the excise; to manage the assay office become vacant by the death of Vauquelin, &c.

The invention of new processes, characterized by exactness, simplicity, and elegance, proves what a slave Gay-Lussac was to his duties, and that the government could not have bestowed its confidence more judiciously.

The academy, called upon to pronounce upon the merits of the alcoholmeter in every-day use, with our colleague, adopted, June 3, 1822, a report, concluding as follows:

"It is obvious, in brief, that M. Gay-Lussac has treated the subject of areometry under every aspect, and with his accustomed skill. The tables he has deduced after a tedious toil of more than six months, will be a valuable acquisition to the industries and sciences; the authorities will find in them also, as he hoped, the means of improving and simplifying the collection of taxes, and the safest guide they can follow."

As fertile in the invention of industrial methods as in the discovery of scientific truths, one after the other, as if by enchantment, Gay-Lussac created chlorometry, invented methods for determining the richness of the alkalies of commerce, contrived ingenious means by which the manufacture of sulphuric acid has become less expensive, and has no longer need to be brought from unfrequented places; and he crowned this series of important works by the discovery of a process which has been substituted in all civilized countries for cupellation, an ancient and defective method for analyzing alloys of silver and copper. Truly, I ask myself, with what theoretical speculations could Gay-Lussac have better filled the second phase of his career, since phase there is, than by producing works which to their scientific merits add the advantage of being susceptible of positive and multiplied applications, which serve as safe guides to the natural industries and to enlighten the public authorities?

To pretend to confine men of genius to the path of pure abstraction, and to forbid discoveries which may be useful to the human race, would be to yield to the most erroneous ideas, in my opinion. And besides, do you wish to know to what you expose yourself when you decide, according to preconceived ideas, what a scientist could do, or should have done?

Gay-Lussac, in your opinion, was in the enjoyment of excellent health, and should have been able, as a septuagenarian, to manifest the ardor, activity, and fertility of intellect of his youth, and a cruel event has proved to you that he bore in his bosom the germ of the disease which carried him off so unexpectedly to scientific Europe.

You thought him entirely absorbed in conducting his business affairs, and at that very time he was constructing, at great expense, in his country-seat, a laboratory which might serve as a model for those chemists who, for themselves or for the public, may have to direct the construction of establishments of the same kind.

Our colleague was represented as exclusively preoccupied with the lucrative applications of science, at a period when, concentrating his faculties to meditate upon numerous and different theories, he was writing the first chapters of a work, which unfortunately he did not finish, entitled *Philosophie Chimique*, (Chemical Philosophy.)

I hope, after these few words, the biographers whose opinions have rendered this digression necessary, will feel, on such occasions, the necessity of confining their explanations simply to the scientific productions which have been submitted to the public, and of remaining silent about those with which, according to their judgment, the scientist should have enriched the world. It is almost preaching ingratitude to posterity.

I should add that the illustrious savants, whose opinions on a special point I have thought it my duty to combat, would likewise like to limit these biographies to purely technical analysis; they would discard everything which concerns the sentiments of the man and the citizen. They allege that details of private life (they call them anecdotes, with a desire to stigmatize them with absolute censure) ought not to be preserved in our academic archives. When, without pretending to show, as might reasonably be done, any comparison between the productions of the early secretaries and my own humble biographies, I reminded these aristarchs of the very interesting portraitures contained in the admirable eulogies of Fontenelle and Condorcet, they replied that everything is good in its time, that the progress of knowledge has rendered the modifications they demand indispensable. I do not share these opinions, notwithstanding the respect due the savants who commend them.

I regard as an essential part of the mission I have to fulfill an investigation into whether the associates whom we have had the misfortune to lose have caused the worship of science and that of integrity to keep pace with each other; whether they have, as the poet expresses it, allied fine talents to a fine character. Nevertheless, in such matters the public is the only competent judge; I will wait until it has made known its sovereign decision, and unreservedly yield obedience to it.

GAY-LUSSAC AS PROFESSOR—HIS LABORATORY—HIS WOUNDS—SIMPLICITY OF HIS MANNERS.

I am going, therefore, without further explanation, to take the liberty of introducing you into those amphitheaters where our colleague delighted with his eloquence a large and brilliant audience. We will then pass into his laboratory; I will even collect various anecdotes, (you see I do not hesitate to use the word,) from which an estimate may be formed, from a new point of view, of the full extent of the loss which the academy has sustained.

In a discussion among the learned to decide whether a treatise on the world was or was not by Aristotle, Daniel Heinsius decided in the negative, and the following is his principal argument: "The treatise in question presents none of that majestic obscurity which, in the works of Aristotle, repels the ignorant."

Gay-Lussac would assuredly never have obtained encomiums from the Dutch philologist, for he always approached his object by paths the most direct, the most distinct, and with the least parade.

Gay-Lussac, on all occasions, showed his profound dislike for those ostentatious phrases into which his first titular professor, notwithstanding his well-merited celebrity, often allowed himself to be drawn, and in which the most pompous words were found side by side with such technical expressions as ammonia, azote, carbon. His language and style were grave, correct, nervous, always perfectly adapted to the subject and characterized by the mathematical spirit which he had imbibed in his youth at the Polytechnic School. He had the power, as others had, of exciting astonishment in his audience by presenting himself before it without any manuscript notes in his hand; but he would have run the risk of using erroneous figures, and exactness was a merit which touched him most nearly.

Gay-Lussac's knowledge of the foreign languages, Italian, English, and German, enabled him to enrich his lectures with erudition of the purest kind, and drawn from the original sources. He it is who has initiated our own chemists and physicists into several theories originating on the right bank of the Rhine. In brief, Gay-Lussac, who has not been surpassed by any contemporary chemist in the importance, novelty, and brilliancy of his discoveries, has also indisputably occupied the first rank among the professors of the capital upon whom devolved the task of teaching the sciences at the Polytechnic School.

On entering Gay-Lussac's laboratory every one was struck, at the first glance, with the intelligent order which reigned everywhere. The machines and different utensils, for the most part prepared by his own hands, were remarkable for the most careful conception and execution. You will pardon me these details, gentlemen. If, as Buffon has said, "Style makes the man," we might add with not less reason that the great chemist and good physicist are recognized by the condition of the apparatus which they use. Imperfections in the operation are always more or less reflected by the results.

When the chemist operates upon new substances and combinations with unknown reactions, he is exposed to real and almost inevitable dangers. Gay-Lussac realized this but too truly. During his long and glorious scientific campaigns, he was seriously wounded on several different occasions; the first time, June 3, 1808, by potassium, prepared in large quantities by a new method. Messrs. de Humboldt and Thénard led our friend with his eyes bandaged from the laboratory of the Polytechnic School, where the accident occurred, to his house rue des Poules, which, by the way, it would be well to call rue Gay-Lussac. In spite of the prompt attention of Dupuytren, he lost the lachrymal glands and thought himself perfectly blind for a month. This disheartening prospect for a man of thirty was borne by our friend with a calmness and serenity that the stoics of antiquity might have admired.

"For nearly a year," said Madame Gay-Lussac, (in a note she had the goodness to send me,) "the reflection from a small night-lamp before which I placed myself to read to him, was the only light he could endure. During the rest of his life his eyes remained red and weak."

The last explosion of which Gay-Lussac was the victim, took place at a period of his life when misinformed individuals declared him to be idle. Our friend was busy with the study of the carbureted hydrogens proceeding from the distillation of oils. The glass balloon containing the gases, and which had been set aside for several days, was taken by M. Larivière, a young chemist, to be submitted to Gay-Lussac's inspection. While our colleague was absorbed in the minute examination necessary to give the projected experiments the desirable precision, a frightful explosion took place, the cause of which, even to this day, is not perfectly understood, which completely shattered the balloon. Such was the velocity of the fragments of glass, that they made on the window-panes of the laboratory clear holes without the trace of a fissure, as if by projectiles from fire-arms. Gay-Lussac's eyes, which were but a few centimeters (not more than an inch) from the balloon, this time escaped all injury; but one of his hands was seriously wounded, and required long and painful treatment. Some persons saw in this terrible wound the original cause of the painful disease to which our friend succumbed a few years afterward.

The members of the academy, who went daily to visit him on his bed of suffering, heard him with emotion congratulate himself that the wounds of his young friend and assistant, M. Larivière, were insignificant, and on this occasion his own life alone had been endangered.

Some have desired to regard these accidents as the consequences of negligence and thoughtlessness; say, rather, by a comparison whose appropriateness will be recognized by all who know our friend, that if he were often wounded it was because he was often under fire, and that he did not hesitate to examine things very closely, even when there was great danger in doing so. It has been thought the successes of Gay-Lussac in his scientific researches only afforded him that calm satisfaction which the discovery of some new truths must naturally produce. Appearances were deceitful. To protect himself from the dampness of the laboratory, which was on the ground floor, Gay-Lussac usually wore sabots over his shoes. Pelouze, one of his favorite pupils, told me that after the success of an important experiment he had frequently seen him through the half-open door of his study give signs of the liveliest pleasure, and even dance in spite of his clumsy wooden shoes.

This reminds me of an anecdote which I will borrow from my friend Sir David Brewster, simply, I confess, that it affords me the opportunity of connecting the name of Gay-Lussac with that of the immortal scientist of whom Voltaire, without being charged with exaggeration, has said:

> Confidants of the Supreme, creatures of immortal life,
> Ye who burn with fire divine, and your wings with glory rife,
> Spread around your Master's throne, can you, from your stations high,
> View great Newton here below undisturbed by jealousy?
>
> Confidents du Très-Haut, substances éternelles,
> Qui brûlez de ses feux, qui couvrez de vos ailes
> Le trône où votre maître est assis parmi vous,
> Parlez: du grand Newton n'étiez-vous point jaloux?

In 1682 the great Newton, turning into account the dimensions of the earth, obtained by Picard, of this academy, renewed a calculation which he had before attempted, but without success, according to the former determinations of Norwood. His object was to ascertain whether the force which retains the moon in its orbit and prevents its escaping in a tangent by virtue of the centrifugal force, was not the same as that which causes bodies to fall at the surface of the earth, diminished only in the ratio of the square of the distances measured from the center of our globe. This time the numerical calculation justified the anticipations. The great man experienced such delight, this coincidence produced so much nervous excitement, that he was incapable of verifying his numerical calculation, as simple as it was, and found himself obliged, for the purpose, to have recourse to a friend.

Let us not omit, when the opportunity occurs, to show that calm scientific labors afford not only more durable emotions than those derived from the frivolities of the world, but that they are often accompanied by the same vivacity.

There was in Gay-Lussac's laboratory, by the side of furnaces, retorts, and apparatus of every kind, a small white wooden table, on which our friend recorded the results of his experiments as they progressed. It was, if I may be allowed the comparison, the exact bulletin written during battle. It was on this little table that were also traced the articles concerning different points of doctrine or questions of priority.

It would be impossible, in relating the life of a man whose chief works date back to the beginning of this century, the period of an entire renovation in chemistry, that we should not have to mention discussions of this kind. These scientific polemics took place especially between Gay-Lussac, Dalton, Davy, Berzelius, &c. You see our friend dealt with doughty antagonists, with adversaries worthy of him. In these discussions our old friend marched straight forward, regardless of any one, with the vigor, let us say more, with the dryness, of a mathematical demonstration. Rarely do we find in them phrases like the balm applied to freshly-made wounds. But how is it that no one has remarked that Gay-Lussac treated himself with a want of ceremony quite equal to that which he used toward others?

The following lines are quoted literally from one of his writings: "The results that I have given," said he, in the Memoirs of Arcueil, "of the different combinations of azote and oxygen are not exact."

Should not he who criticises his own works so frankly be excusable for being so exclusively preoccupied with the interests of truth in examining the works of others?

MARRIAGE OF GAY-LUSSAC—HIS LOVE FOR HIS NATIVE LAND—UNCHANGEABLE DEVOTION TO HIS FRIENDS—HIS NOMINATION TO THE PEERAGE.

Those who only knew Gay-Lussac slightly, fancy there could have been no romance in his private life. Perhaps they will change their opinion after hearing this recital.

There was, in Auxerre, at the beginning of our first revolution, a musical artist who was attached to the four large societies and to the college of that city. The suppression of these establishments, in 1791, brought great pecuniary troubles upon this respectable family. The artist did not, however, lose courage, and devoted the small fortune of his wife to the education of his three daughters, whom he wished to fit for the honorable position of governess. But the eldest of these young girls, Josephine, becoming aware of the narrowness of the means of her parents, and of the sacrifices they would have to endure before attaining their object, earnestly begged to be placed in a mercantile establishment in Paris, to remain there until the ages of her sisters and their education should enable them to realize the hopes entertained for them by their parents.

It was at a linen-draper's, the usual refuge of women of all conditions and ages, whose lives had been disturbed by revolutions, where Josephine had placed herself, that Gay-Lussac made her acquaintance. He saw, with curiosity, a young girl of seventeen seated behind the counter holding in her hand a small book which seemed to fix her attention deeply. "What are you reading, miss?" he said. "A work, perhaps, beyond my comprehension; it interests me, however, much—a treatise on chemistry." This singularity excited the interest of our young friend; from that moment the unusual necessity for linen ware brought him constantly to the draper's, where he entered repeatedly into conversation with the young reader of the chemical treatise; he loved her and was loved in return, and obtained from her a promise of marriage. Our illustrious colleague, as a future marriage dower, placed Josephine in a boarding-school to complete her education, and especially to learn English and Italian. Some time after she became his wife. I would not venture to advise this rash fashion of choosing a wife, although our celebrated chemist perfectly succeeded in it.

Beautiful, sparkling with wit, brilliant, and admired in society, for which nevertheless she cared but little, for the grace and distinction of her manners, Madame Gay-Lussac constituted for more than forty years the happiness of her husband.

From the beginning, they adopted the amicable custom, the consequence of some slight mutual concession, of merging their thoughts, desires, or sentiments into one thought, one desire, one sentiment common to both. This identification in everything was such that they ended by so entirely having the same handwriting that an amateur of autographs might readily believe that a memoir copied by Madame Gay-Lussac had been written by the celebrated academician.

Three days before his death, touched by the infinite solicitude lavished upon him, Gay-Lussac said to his wife, "We will love each other to the last; the sincerity of attachments is the only happiness." This tender, affectionate language will not spoil the portrait I have desired to draw of our colleague.

Gay-Lussac's demeanor was always very grave; he entered frankly into the bursts of merriment that a well-chosen anecdote created in societies where he was surrounded by his friends, but he never provoked them himself.

Gay-Lussac carried his love for his native land so far as never to be willing to be witness of a performance of "Pourceaugnac," brought out by Molière at Limoges; his joy, therefore, knew no bounds when there appeared, under the name of "Nouveau Pourceaugnac," a vaudeville by M. Scribe, in which the principal character, M. de Roufignac, also a native of Limousin, instead of being mystified, renders all the other actors the sport of his witty mystifications.

It is related that La Fontaine, at one time, accosted all his friends with, "Have you read Le Prophete Baruch?" So it was with Gay-Lussac; he never failed, no matter how little the circumstances authorized it, to ask with candor equal to that of the fabulist, "Do you know the 'Nouveau Pourceaugnac?' It is a charming piece; I advise you to go to see it." And I must say for him that, though so saving of his time, he preached by example.

A single fact will suffice to show that Gay-Lussac gave himself up enthusiastically to the honest inspirations of his soul, when necessary, even at his own risk and peril, to baffle an intrigue or defend a friend. At the second restoration it had been decided in high places, it was said, to remove a professor, whose liberal sentiments had rendered him an object of suspicion, from the Polytechnic School. But how effect this dismissal without exciting great opposition? The professor was zealous, respected, and even, I must say, beloved by all his pupils. The case was embarrassing, when it was discovered that this victim of public animosity had during the hundred days signed the additional act. The professor of literature (it was not, let it be well understood, M. Andrieux, but his successor) undertook to make every use of this discovery. In a meeting of the corps of instruction he declared that, in his opinion, those who gave their support to the usurper, that Corsican ogre, whatever might be their motives, were not worthy to lecture before the youth to whom the future of the country was to be confided; they should themselves decline to officiate. The member of the corps of professors against whom this attack was directed asked permission to explain himself, when Gay-Lussac arose impetuously, interrupted his friend, and announced in a sonorous voice that he also had signed the additional act; that he would not hesitate in the future to sustain the government, whatever it might be, even the government of Robespierre, when the enemy threatened the frontiers; that, if the patriotic sentiments which guided him were a subject of reprobation, he formally demanded that the proposed reformation should begin in his person.

The professor of literature saw, therefore, that his proposition would be followed by consequences which would far exceed the limit within which he wished to confine it, and no more was said.

Berthollet died in 1822; it was then known he had bequeathed his sword, an integral part of his costume as peer of France, to Gay-Lussac This bequest excited much surprise. But it will be found quite natural if we follow out the chain of ideas which influenced the venerable academician.

As the most illustrious of our chemists, Berthollet had been senator under the empire and peer of France during the restoration. Should we be surprised that he was persuaded, that a science which was the source of glory and wealth to our country, should not cease to be represented in the highest tribunals of the state? When near his end, Berthollet examined, with the independence, tact, and judgment usually displayed by the dying, to which of the living chemists this honor should revert; his opinion was decidedly in favor of his friend and colleague Gay-Lussac; which he testified as fully as his habitual reserve allowed him, by giving him a part of his future costume as peer. This was what this gift signified, which it would be very difficult to understand without this explanation. Berthollet had often heard, while in Egypt, of the symbolical language of flowers, frequently used by Mussulmans, and a language which is the pride of many oriental poets. The circumstance just related is but an extension of those poetical usages. The venerable academician expressed, by the gift of an object so little in harmony with the ordinary occupations of Gay-Lussac, the esteem he felt for our friend and his inviolable attachment. This act of enlightened justice however, was not realized as promptly as was hoped. "Why," said the friends of Gay-Lussac to the dispensers of royal favors, "why make him wait so long for a reward which he must receive sooner or later? Do you think him not sufficiently distinguished?" "You wrong us," they reply. "Have you any fault to find with his connections?" "We are not ignorant that they are all honorable and of gentle birth." "Is it by any accident a question of fortune?" "We know that Gay-Lussac enjoys an ample competence, the fruit of his own labor." "What, then, is the obstacle?" And then they acknowledged, softly, very gently, shrouding themselves in mystery, as if ashamed of such an avowal, that the great chemist worked every morning with his own hands at the assay-office, which seemed incompatible with the dignity of a peer of France.

Such was the wretched motive which, for several years, interfered with the fulfillment of Berthollet's ingenious horoscope. Indeed, it is difficult to imagine that a man can degrade himself by working with his hands in attempting to prove the reality of his theoretical conceptions.

To take an instance at random, and from foreign sources, do the discoveries of Huygens and Newton forfeit any of their importance and brilliancy because the first made spectacles and the second telescopes with their own hands? Are the immortal views of Herschel on the constitution of the heavens at all lessened for having been obtained by instruments fashioned by the illustrious observer himself?

Has a single voice in the House of Lords, so proud of its ancient privileges, been raised to claim that Lord Ross had recently degraded himself by becoming in turn founder, forger, and polisher of metal, when, by this triple qualification, he has endowed the science of astronomy with the colossal telescope, now one of the marvels of Ireland?

Could there be a puerility more worthy of contempt than that of which he would be guilty who could ask, at the time when Watt was trying, by the most careful experiments, to give the steam-engine that perfection which makes it the glory of the inventor and the power of his country, whether the hands of the illustrious mechanician were covered with iron-rust or coal-dust? At all events, reason finally triumphed over prejudice, and Gay-Lussac was admitted into the House of Peers.

DEATH OF GAY-LUSSAC—HIS LAST WORDS—HE CAUSES THE TREATISE ENTITLED PHILOSOPHIE CHIMIQUE TO BE BURNED.

Gay-Lussac saw his end approach with the resignation which a pure conscience must inspire. He not only faced death with calmness, but even the *act of dying*, as Montaigne might have said.

When the sad news fell like a thunderbolt upon Paris that the health of our colleague was a cause of great solicitude, one of his friends immediately wrote to the afflicted family who surrounded him to learn the truth. Gay-Lussac desired to reply himself. The following were the words of the dying man:

"MY DEAR ARAGO: My son has just told me of your letter to him. It is but too true; I have one foot in the grave, which must very soon close over me; but I gather all my strength to thank you for the interest you take in me, and to tell you that the mutual affection of our two families has been a source of great happiness to me all my life.

"Adieu, my dear Arago."

Do not imagine, gentlemen, for a moment, that I could, on this solemn occasion, wish to make a parade of sentiments so unaffected, to spontaneous, and so free from that straining after effect which formerly led Madame de Sévigné to describe the friendships of the dying hour. A self-deception emanating at all events from the heart would be forgiven.

The forebodings of Gay-Lussac, his family, and the public yielded every moment to more encouraging anticipations. Our colleague Magendie, who had hastened to his old friend with his scientific skill, was, for a short time, himself deluded by this general hope.

Gay-Lussac was removed to Paris, where his condition for some days seemed to improve. He spoke to us then of his future work, and of the regret he felt, at a time when there seemed no possibility of prolonging his life, at having given an order to his son to burn his treatise, *Philosophie Chimique*, the first chapters of which were nearly finished. But he was soon forced to abandon all hope.

The dropsy, with which he had been suddenly attacked, made rapid progress, and our friend expired quietly and bravely on the 9th of May, 1850, at the age of seventy, and he might have said with one of ancient times, "If it were given me to live my life over again, I would on all ocasions do as I have done."

The obsequies of the learned academician were solemnized May 11, in the midst of a large concourse, including nearly the entire body of his early associates of the Academy of Sciences, and some of the most distinguished members of other acadamies; the entire institute testified in this manner that it could not at that time have suffered a greater loss. The early pupils of the Polytechnic School, the entire body of the two present classes of the school, the friends of science, and many grateful auditors of the two excellent courses of the Sorbonne and the Jardin des Plantés, also joined in the funeral procession.

The various political opinions which unhappily divided our country were blended together in this mournful train, and who could, indeed, say to which of these parties Gay-Lussac belonged? What party could flatter itself to have numbered the illustrious scientist in its ranks? The compatriots of our colleague once intrusted him with the honor of representing them in the Chamber of Deputies. Later, as we have seen, Louis Philippe made him peer of France; but he approached the tribunes of these two assemblies very rarely, and only to discuss special questions relating to his favorite studies. Should this reserve be attributed to timidity, or can it be simply explained by Gay-Lussac's desire not to introduce any disturbing elements into the even current of his life? If this last supposition be correct, he was perfectly successful. Never did the foulest of all calumnies, political calumny, attack the scientific career of our associate. His works have escaped the daily criticisms of those hireling writers who, before taking up the pen, ask themselves, not what are the real merits of the memoirs whose analysis they are about to publish, but what are the supposed opinions of their authors upon the exciting and yet perplexing questions of social organization. The discoveries of our colleague have always been appreciated in France at their just value. We can, therefore, say of him, in the words of Voltaire, written under a portrait of Leibnitz, "Even in his own country he lived respected."

The recollections of the profound friendship which bound me to Gay-Lussac for more than forty years have perhaps tempted me into too minute details in writing his biography. However that may be, I will sum up the history of this beautiful life in these few words: Gay-Lussac was a good father, an excellent citizen, an honest man in every event of his life, an ingenious physicist, and a peerless chemist. He honored France by his moral qualities, and the academy by his discoveries. His name will be uttered with admiration and respect in every land where science is cultivated. Finally, the illustrious academician will live forever in the hearts and memories of all who had the happiness to rejoice in his friendship.

BIOGRAPHICAL SKETCH OF DOM PEDRO II, EMPEROR OF BRAZIL.

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[Translated for the Smithsonian Institution by M. A. Henry.]

PREFACE.

About a year ago the telegraph announced the intention of the Emperor of Brazil to visit the United States, and the countries of the north of Europe he had omitted in his first tour in 1871. Remembering the favorable manner in which the journals had at that time spoken of the distinguished traveler and of his reign, which has lasted now for forty-five years, I determined to prepare an account of both for the public, although under a very abridged form.

We offer then to the reader only a biographical sketch, for we have no intention of encroaching upon the domain of future historians, particularly as the reign of Dom Pedro II has not yet terminated, but we are happy to be able to furnish some well established facts, which may serve as a foundation for a more extended work, superior to ours in style and form, although not in truthfulness of statement.

Before touching upon the place in Brazilian history occupied by the reign of Dom Pedro II, let us glance rapidly over the history of Brazil, from its discovery to the ascension to the throne by its present Emperor.

INTRODUCTION.

HISTORY OF BRAZIL FROM ITS DISCOVERY UNTIL THE ASCENSION TO THE THRONE BY DOM PEDRO II.

About the end of the year 1499 and the commencement of 1500, three Spanish navigators, Alonzo de Hojeda, Vicente Yanes de Pinçon, Diogo de Lepe, and the Portuguese admiral, Pedro Alvares Cabral, landed successively at different points of the coast of Brazil, whose existence at that time was entirely unknown. Although Cabral had been preceded by the three Spanish navigators, and owed his discovery only to the circumstance of having involuntarily wandered from the route he should have followed for the Indies, the king of Portugal, Dom Manoel was the first to announce to Europe this important discovery, and to take possession of the new country, to which the Portuguese gave the name of Brazil, on account of the well known wood of that name which abounds there. Brazil thus became a colony of Portugal.

By nature rich beyond expression, and seeming only to await the hand of civilized man to yield every possible profit, Brazil was for Portugal an inexhaustible mine of wealth, with this important advantage, that its great distance from all European nations shielded it from invasion.

The importance of the possession of Brazil was especially felt by the royal house of Portugal, when Napoleon threatened to seize their country and join it to Spain, (treaty of Fontainebleau in 1807.) This circumstance determined the prince regent, Dom Juan, to intrust the defense of the kingdom to England, and to embark himself for Brazil with all his family, and a numerous court. Brazil thus became the seat of the Portuguese royalty, and was afterwards raised to the dignity of a kingdom.

The residence of the royal family in the country was prolonged to 1821, that is to say, until a large party in Portugal, discontented with what appeared to be a desertion of their country by their sovereign, and also on account of the commercial relations Brazil entertained with the rest of the world, contrary to the ancient monopoly accorded to Portugal, excited a revolution which soon extended over the entire country, and at last obliged the king to return to Portugal. On leaving for Europe, Dom Juan placed at the head of the government of Brazil his son Pedro, heir presumptive to the throne.

It was not without grave apprehensions that the king quitted Brazil, for there had been several attempts to attain the independence of the country, and the most enlightened of its patriots still entertained hopes of eventually securing its freedom. Foreseeing the impossibility of subduing these revolutionary efforts sufficiently to prevent a recurrence of them, and at the same time knowing the monarchical tendencies of the majority of the Brazilian people, he on his departure very wisely counseled his son to place himself upon the throne in case a separation of Brazil from the mother country appeared inevitable.

After the return of the royal family to Portugal, the Cortès resolved to reduce Brazil to its former state of a colony, and compelled the king to adopt certain reactionary measures which outraged the dignity and aroused the patriotism of the Brazilians. The Cortès in fact forgot that in the moral as well as the physical world it is not possible to attempt to repress what is irrepressible without danger of explosion or rupture.

The prince regent of Brazil, Dom Pedro, hardly twenty-three years of age, saw these indications of discontent with uneasiness. His situation became more and more embarrassing. It was difficult for him to decide what, under the circumstances, was his duty: for if, on the one hand, he desired to enforce obedience to the sovereign authority of Portugal, on the other, he found the nation quite ready to proclaim him as king, but also determined not to hesitate even in the use of force, if necessary to secure independence. There was in his mind a terrible conflict between the apparent duty—which he had not the strength to discharge—and the noble ambition of preventing the return of a people who had tasted of the sweet cup of liberty to a colonial condition. Added to the latter consideration was the fact that his father and sovereign had in advance released him from the loyal adherence which was his due, and had himself suggested the solution of the question of Brazilian independence, if it were irresistibly presented.

Under these circumstances, the Portuguese Cortès themselves relieved Dom Pedro of his embarrassment; first by the issue of orders tending to deprive him of all administrative authority over the Brazilian provinces, and finally by his recall to Europe. The departure of the prince would have compelled the Brazilians to assert their rights by the demand for another occupant for their throne. The moment was decisive, and the Brazilians understood this so well that they entreated Dom Pedro to remain in the country, in order that the contest might be avoided which must inevitably ensue, and also that he might assist them in securing finally their independence. Dom Pedro yielded to the desire of the nation, expressed to him through its legitimate representatives, in words which have become celebrated in the history of Brazil: "*Since it is for the good of the country, I remain.*" Brazilian independence, under the form of a monarchy, was decided from that moment. Whether Dom Pedro was actuated entirely by ambition, or solely by the desire to found a free state—which is much more in accordance with his chivalrous disposition—there was now for him no honorable retreat. Like Cæsar, after passing the Rubicon, contrary to the orders of the Roman senate, he could say, "*Alea jacta est!*"

Events followed in rapid succession. The resolution to remain in Brazil contrary to the expressed orders of the mother country was taken on the 9th of January, 1822. Only four months after, the young prince accepted the title of *Perpetual Protector of Brazil*, offered to him by the municipality of Rio de Janeiro in the name of the nation, and on the 12th of October of the same year he was proclaimed Emperor, under the name of Dom Pedro I. The independence of Brazil was thus peaceably obtained, for the Portuguese garrisons in the country made but slight resistance and were soon overcome.*

The empire established, it was necessary to give it a constitution, but the discussion of this important document led to very serious disagreements between the members of the chamber of deputies and the sover-

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* The independence of Brazil was recognized by Portugal in the treaty of the 29th of August, which imposed upon the country the payment of two millions of pounds sterling.

eign, who at last summarily dissolved the legislative body. We can easily understand the irritation this act produced in the nation. The Emperor, in order to calm the disturbance and restore public confidence, prepared, in 1825, a most liberal constitution. But unbiased judgment was no longer possible; misunderstandings again occurred in regard to the execution of this fundamental code; for, on the one hand, the Emperor, who had been reared in absolutism, had a natural tendency in that direction in spite of himself, and, on the other hand, the liberals wished to efface this element completely from the government in order that they might rule. Fault existed on both sides. The fact was, the political parties, as well as the sovereign, were novices in parliamentary government. A curious incident shows the state of public feeling at this time. On the 25th of March, 1831, anniversary day of the adoption of the constitution, the Emperor went, according to custom, to church to assist in the *Te Deum* announced for the occasion. On his entrance there was a cry of "Long life to the Emperor!" followed by "As long as he is constitutional!" The Emperor turned toward the portion of the audience from which the latter came, and said in a firm, clear voice, "I am and have always been a constitutional sovereign!" This, however, did not prevent discontent from increasing every day.

On the 6th of April the Emperor, considering his ministers inefficient, dismissed them and appointed others. The malcontents seized upon this occasion to promote a revolt, in which the garrison of the capital participated. The insurgents sent messengers to the sovereign to demand the restoration of the dismissed ministers, under the pretext that the new officers had not inspired the people with sufficient confidence. The Emperor replied, "*I will do everything for the sake of the people, but nothing by force of the people;*" and, although he could count upon the support of the Portuguese part of the community, and of the troops of that nationality, in the maintenance of his authority, he preferred to abdicate in favor of his son rather than shed the blood of his countrymen. He signed the act of abdication the next day, the 7th of April, and set sail a few hours afterward for Portugal, where he re-established his daughter, Maria da Gloria, upon the throne which her uncle and husband Don Miguel had usurped. His son, in whose favor he abdicated the throne of Brazil, is the present Emperor Dom Pedro II.

DOM PEDRO II.

I.

Dom Pedro II was the offspring of the marriage of the Emperor Dom Pedro I, of Brazil, founder of the empire, and descendant of the house of Bragance, of Portugal, with the Archduchess Leopoldine, of Austria, and of the house of Hapsbourg.* He was born at Rio de Janeiro on

* The Princess Leopoldine was the sister of the Archduchess Marie Louise, who became Empress of the French by her marriage with Napoleon I.

the 2d of December, 1825; and had hardly completed his fifteenth year when his august father abdicated in his favor, in accordance with the constitution, which prescribed that with the same degree of relationship, preference should be given to the masculine sex.* His name is Pedro d'Alcantara Joao Carlos Leopoldo Leocadeo Miguel Gabriel Raphael Gonzaga; his title, *Constitutional Emperor and Perpetual Protector of Brazil.*

The childhood of this prince was far from happy, for his mother died the year following his birth, and his father was engaged in the harassing and almost daily political struggle which terminated with his abdication. It is doubtful whether, under the circumstances, Dom Pedro I had the time to attend, as he would have desired, to the education of his children. They did not even witness his departure, the Emperor having determined suddenly in the night to abdicate and leave the country. He did not wish to disturb the peaceful slumber of his children, and contented himself with embracing them several times very tenderly and with tears. It was a sad spectacle, this valiant soldier, who had many times braved the danger of revolutionary crises, weeping in the presence of his court, his ministers, the embassadors of France and England, his friends, and his faithful generals.

Imagine the sorrow of his children the next morning when they received, instead of the paternal kiss, the sad news of the departure of the father they would perhaps never see again. Although Dom Pedro, on account of his extreme youth, could not feel all the importance of such an event, his tears, and the manner in which he pressed in his arms his young sisters, testified to the extent of his grief. How many children of the people were at that moment happier in their cottages than he in a palace, notwithstanding he had just come into the possession of an immense empire.

II.

According to the Brazilian constitution the Emperor is a minor until the age of eighteen years, and during his minority the empire must be governed by a regent, the member of the imperial family the most nearly related to the Emperor, provided always such relative is more than twenty-five years of age. In case there should be no relative fulfilling this condition, it is the duty of the chamber of deputies and the senate to nominate a permanent regency composed of three members, the oldest of which is the president. This was done, and the regency, consisting at first of the required number of persons, was, a few years later, after the reform of the constitution, reduced to one, elected by the nation for a term of four years.

The men who were successively called to the noble task of preparing

*Of the surviving sisters of Dom Pedro who remained in Brazil, one, the Princess Doña Francisca, was married in 1843 to the Prince of Joinville; the other espoused Prince Louis de Bourbon, Count d'Aquila, in 1844.

Dom Pedro to govern his empire, acquitted themselves in a manner worthy the honor and gratitude of their countrymen. While endeavoring to establish the empire of law in this nation distracted by anarchy, the regents never for a moment forgot the physical and intellectual education of the young monarch. The principal direction was intrusted to the bishop of Chrysopolis, to the great satisfaction of all acquainted with this venerable gentleman, eminent not only for his virtues, but also for his great attainments.

Under this wise and paternal instruction, Dom Pedro, with his two young sisters for companions, passed his days in the midst of books and toys, with all a child's unconscious freedom from care, when he received the terrible news of the death of his illustrious father (1834). He had not then completed his tenth year. The intelligence, which was as unexpected as sad, produced in his youthful mind, after an interval of the most violent grief, a complete change; he became grave almost to sadness, while all his actions and words seemed to be carefully considered. This transformation can be very naturally explained. The young prince, deprived of his mother, had settled all his filial affection and hopes upon his father. His confidence in the power of the parent, who had bequeathed to him his rights as a monarch, to draw the sword if necessary to maintain them intact, as he had done for his daughter in Portugal, was in accordance with the ideas of his age. This prop suddenly withdrawn, this powerful moral support lost to him, he felt the necessity of self-reliance and of preparation for the gulf which might any moment open under his feet in a country where the ambition and the vanity of the political men were unbounded, while moral as well as material law were absolutely wanting. He then very naturally determined to make a man of himself, to seriously prepare not only to guard against danger, but also to meet it if necessary. A happy inspiration taught him that the surest way to this end was the acquirement of superior knowledge, of science in all its branches. The most learned professors, national and foreign, to be found in the country or that could be obtained from abroad had been provided for his classical studies, and later, others were intrusted with his instruction in philosophy and mathematics as well as the natural, moral, and political sciences. Although pursuing all these branches with equal facility and like ardor, he had for the natural sciences a marked preference amounting to enthusiasm. His application to study soon produced results which excited the admiration of those who surrounded him, but also caused uneasiness to the bishop of Chrysopolis and the regent in the fear that he might injure his health by too great application. It is related that one evening the venerable instructor was obliged to remonstrate seriously with his young pupil because the latter had fallen into the habit of relighting his lamp for study after it had been extinguished by the bishop for the night.

The fruits of his industry soon became evident in his conversation, which was remarkably intelligent for one of his age, nor was it without a certain satisfaction that he exhibited his attainments, unusually varied and solid for a youth of fourteen. We shall see later how this love of study was turned to the great advantage of his country.

III.

In 1840 Dom Pedro was in his fifteenth year. Civil war had for five years desolated the province of the Southern Rio Grande, the most important and the strongest portion of the empire, as far as regarded means of defense from the neighboring countries of the Plata. This condition of political disturbance in one portion of the empire, with the ebullition of a rebellious spirit under forms more or less violent in various parts of the country, ended by producing a general feeling of discontent, which in the capital assumed more and more of a threatening character.

This state of things exactly suited idle mischief-makers and ambitious, unscrupulous politicians. *The public good, the welfare of the country, state reasons*, and other high-sounding phrases of the same character, not without their effect when skillfully used, especially in a country whose organization is still imperfect, were the order of the day both with the press and in places of public business. At this period two political parties appeared to predominate over the various factions which divided the country. Their tendencies were in general the same as the two opposing parties in a constitutional government—the liberal and the conservative. The former, which was in the minority in the chambers, whether eager to obtain power, or wishing to recommend itself to the supreme head of the nation, perhaps because really convinced that the good of the country required a radical change in the personnel of the administration, proposed, through its representatives in the session of parliament, that the young prince should be declared of age. This project was lost in the senate, and when presented a month later to the house of deputies, excited the most stormy discussions ever known in Brazil. Finally, the regent (Senator Pedro de Aranjo Lima, afterward Marquis of Olinda) determined to order an adjournment of the chambers. In the state of public feeling this act was certainly impolitic; and the communication of the decree to the chamber of deputies (July 22, 1840) was like setting fire to a powder-mine ready for an explosion. It produced immediately violent excitement. The authors of the project for declaring the Emperor of age and its principal supporters quitted the hall immediately, and collecting adherents in the streets proceeded to the senate, where they joined the few members of that body in favor of the proposition. They then sent to Dom Pedro a deputation, with a communication signed by five senators and three members of the house of deputies, in which it was declared that "the adjournment of the legislative chambers at the moment when the majority of the Emperor was proposed was an insult to his august person, as well as treason to the nation; and in view of the great evils which must accrue to the tranquillity of the capital from such an adjournment, since the enemies of public peace would take advantage of this event to disturb society to its foundation, the Emperor was entreated to save the country and the throne by taking into his own hands, *from that moment*, the exercise of the high attributes the constitution conferred upon him. Instead of resisting with firmness this demand, the regent left Dom Pedro to his own unadvised inspirations, and demanded of him, in the presence of the delegates, whether he would accede to their desires. The young prince, much agitated, answered, "*Yes.*" What other response could he make, face to face with anarchy and threatened revolution, especially after the weakness manifested by the government.

This was on Wednesday. The regent immediately announced his intention to convoke parliament for the following Sunday, in order that the majority of the Emperor might be publicly declared according to the constitution. A member of the deputation objected to any delay, and proposed that this convocation should take place the next day. On the following day, therefore, the 23d of July, Dom Pedro II was declared of age by the president of the general assembly of the representatives of the nation, and on the same day took the oath imposed by the fundamental law of the empire. This political event excited great enthusiasm throughout the entire nation; weary of the often bloody struggles of the factions, there seemed hopes of a better future in the political emancipation of the prince. In consequence of this emancipation the liberal party were brought into power. The minister pronounced the chamber of deputies dissolved, and decided that the Emperor should be crowned the following year.

IV.

Behold Dom Pedro then governing by himself his vast empire. The burden he had assumed, or rather which had been placed upon his shoulders, afforded grounds for reflection for more than one sincere friend of the monarchical form of government and of the reigning dynasty; for from 1831, the period of the abdication of the first Emperor, to 1840, the majority of his son and successor, none of the statesmen who had held the reins of government had been able entirely to control anarchy and the ambitious spirits who aspired either to the central government or to that of the provinces, which they saw in their audacious dreams converted into independent republics. In fact the first years of the government of Dom Pedro did not pass without danger to the monarchy. First, the serious revolution of the province of the Rio Grande had not been entirely quelled, and there seemed no near prospect of its termination; then the struggle between the liberal and the conservative party, both through the press and in the tribune, assumed a more and more violent character and ended by an actual contest at arms.

The conservative party, in return for the prompt action by which the liberal minority had obtained the power and forced consent to the majority of the Emperor, induced the young and inexperienced monarch to dissolve the new liberal chamber even before it had assembled, on account of alleged violence and fraud committed during the election, and placed itself at the head of the administration of the government of the country. The liberals followed this defection by the revolution of 1842, in two of the largest provinces of the empire—Minas-Geraes and S. Paulo—but were soon subdued. However, their exclusion from the government was not of long continuance, for two years afterwards we see them again in power, to be reversed anew in 1848. Again they took up arms, this time at Pernambuco. The contest was bloody, but happily did not last long, and the rebels were conquered as before. If the young Emperor had not at this time sufficient experience in the government of men to avoid these fratricidal struggles, he had an opportunity of manifesting his conciliatory disposition by using one of the most beautiful prerogatives granted him by the constitution—that of remission of punishment, and pardon of the guilty.

The conservative party, in 1845, brought to an end the important revolution of the Rio Grande, and gained by this new success a prestige and reputation for order which maintained it in power until 1863.

The Emperor was married, by power of attorney, in 1843, to the daughter of Francis I, King of the Two Sicilies, the Princess Thérèse Christine de Bourbon;* and in 1845 he made with her a journey through the southern provinces of the Rio Grande and S. Paulo, to study for himself the means of avoiding the return of discontent.

V.

Order was hardly restored (after the revolution of 1848) when the attention of the government was called to the neighboring countries of La Plata, under the despotic rule of General Rosas, President of the Argentine Confederation.

This audacious *gaúcho* had conceived the project of re-establishing for his own benefit the ancient Spanish vice-royalty of La Plata, which included the territories known to-day under the names of the Argentine Confederation and the republics of Paraguay and Uruguay.

Foreseeing the danger that must necessarily arise from an increase of the power of Rosas to Brazilian commerce, a part of which was carried on by river communication with the Brazilian province of Matto-Grosso, the imperial government was making preparations to oppose this measure, when Rosas, by his hostile attitude toward Brazil, which he

* Of this marriage was born two princes and two princesses. The princes are dead; also the younger of the two princesses. The latter, the Princess Léopoldine, was married to the Prince Louis Auguste Marie de Cobourg-Gotha, Duke of Saxe. The surviving princess, who bears the title of princess imperial, because she is the heir presumptive to the crown, is called Isabel. She is married to Prince Louis-Philippe-Marie-Ferdinand-Gaston d'Orleans, Count d'Eu, and son of the Duke de Nemours. The Princess Léopoldine left four children. The princess imperial has only one son, who is by the constitution her successor to the throne.

accused of taking part with his enemies, himself furnished a pretext for declaring war.

Brazil then formed an alliance with General Urquiza, governor of a province of the Argentine Confederation in revolt against Rosas. Their united forces marched against the despot and vanquished him on the 2d of February, 1852, at Monte-Casero, not far from Buenos Ayres. Rosas embarked the same day for England.

VI.

From this period really began that progress which excites the admiration of all who compare the Brazil of the present with the Brazil of twenty-five years ago. This beautiful era in the history of the vast empire commenced with the abolition of the slave trade an immense step toward civilization, followed by a veritable enthusiasm for commercial and industrial enterprises; then were laid the first railroads, the especial lines of which, such as those of state, received the guarantee of an interest of 7 per cent.; the companies for river and maritime navigations were largely increased; Europe was brought into communication with Brazil by means of steam; gas was introduced into all the great cities, and good roads were opened. Most of these enterprises gave to agricultural industry, especially to the culture of coffee, sugar, tobacco, and cotton, a marked impulse, and were thus of material benefit to all classes of society.

The satisfactory condition of the country allowed Dom Pedro to make an excursion of several months to the northern part of Brazil, (1859.) He visited in succession the provinces of Bahia, Pernambuco, d'Alagoas, and Parahyba. He was everywhere welcomed with great enthusiasm, and received such warm ovations that it may be said his journey was one continued *fête*, by which the people endeavored to express their love and gratitude for the great benefit they had received through his wise government. This visitation of the empire was of the greatest utility in a particular as well as general point of view. For everywhere the Emperor endeavored to learn for himself the degree of intellectual and material development of the provinces, what was needed to secure their progress, and especially the manner in which the governors administered their office.

On his return to the capital he took the necessary measures, in conformity with the information he had obtained, for the benefit of the provinces he had visited.

VII.

This peaceful prosperity, which lasted ten years, was suddenly disturbed by a double incident known under the name of the *English Conflict*, and worthy of notice because evincing the energy of Dom Pedro, when called to maintain the dignity of the nation of which he is the head, and also the ardent patriotism of the Brazilian people.

Towards the end of 1862, some officers of the English navy had, in the garb of peasants, deserted from a military post in the vicinity of Rio; they were seized in a brawl by the civil authorities and imprisoned until they could be identified, which was done the next day. The English government claimed satisfaction for their detention, but the Brazilian government, believing no satisfaction was necessary, submitted to the decision of Leopold I, King of Belgium, the question whether the English navy had cause for offense. The Belgian monarch replied in the negative. But, before this decision was received, the minister from England at Rio, (Mr. Christie,) either because he was angry with the Brazilian government for refusing the satisfaction demanded, or foreseeing the sentence of the king of Belgium, and not wishing to remain under the unfavorable impression of a condemnation he had himself provoked, demanded and obtained authority from England to require of the Brazilian government an immediate settlement of a claim which had been under consideration for two years, and which necessitated the payment of a sum of money (6,000 pounds sterling) as indemnity for the losses resulting from the shipwreck of a small English vessel upon the coast of Brazil. This was the second incident. The imperial government refused to comply with the demand before the claim had been fully discussed. The English minister then ordered the commander of the English squadron stationed in the Brazilian waters to exercise the act of reprisal until the sum named was paid. As soon as this order was known the entire populace of the capital arose in indignation, and a large body, carrying the national colors, proceeded to the palace of S. Christovam,* the ordinary residence of the Emperor, and encountering the sovereign on the way, conducted him in triumph to his city palace, where the monarch had already called a council of the ministers. It was on this occasion Dom Pedro uttered these memorable words, which secured to him forever the love of the Brazilian people: "*I desire above all to show that in the presence of danger I am the equal of every other Brazilian citizen.*"

Although the ministers shared the indignation of the sovereign and the people at this uncalled-for violence on the part of a foreign power, still, as responsible for any measures taken, it was necessary to reflect carefully before acting. The opinion was earnestly maintained that force should be met with force, but by the minority. After a long deliberation, it was concluded that a contest upon the sea, although offering some advantages in the commencement, would at last become too unequal to be continued with any chance of final success; it was therefore decided that the government should agree to pay the required sum, but directly to the English Government, provided the latter persisted in the demand made by its representative at Rio. The English Government insisted, and the sum was paid, but under protest.

The Emperor, considering the conduct of the English government as

* The palace of S. Christovam is in the suburbs of the capital.

an act of mere caprice, withdrew his representative at London; which determined the recall of Mr. Christie. Diplomatic relations were not restored between Brazil and England until three years later, and then through the intervention of the King of Portugal.

It is a common saying "*that evil always has its good side.*" The conflict with England was not without advantage to Brazil, in that it manifested the weakness of the country as compared with the great maritime powers, and showed the Brazilians that they should not confine their attention exclusively to interior prosperity, but should also acquire the means of responding suitably to any exterior insult.

A number of respectable citizens then conceived the happy idea of raising a permanent national subscription for the purchase of modern cannon and iron-clad vessels. This was met with enthusiasm by the nation; donations were received from all sides; the Emperor subscribed the *fifth part* of his civil list; the empress and the princess followed his example, the public functionaries and the officers of the army gave 5 per cent. of their salaries; the rich land-holders promised large amounts; the poor also, to the extent of their ability, manifested their patriotism. The subscription amounted in a few months only, to a sum of several millions. Large orders were then sent to Europe for all kinds of war-engines, while the armories of the country worked with an activity before unknown. The Emperor himself manifested indefatigable energy; he visited every day arsenals, workshops, dock-yards, fortresses, war-vessels, military schools, and everywhere exhibited knowledge which astonished even specialists. All these efforts were crowned with brilliant success, as we shall see. But first we would mention that about the middle of 1863 the conservative party was obliged to give way before the liberal party, which came into power by the elections following the dissolution of the Chamber of Deputies, in which the conservative majority had become doubtful.

VIII.

In April, 1863, occurred in the republic of Uruguay, adjoining Brazil, a revolution, at the head of which was General Flores. The government of Uruguay could not subdue the insurgents for want of men and money, and had, like its predecessors, recourse to violent incursions upon the property of the Brazilians living on the frontiers of the republic, taking from them especially their herds of sheep and cattle. Under these circumstances many subjects of the empire were maltreated and even forced to enroll under the flag of the republic.

The government of the Emperor remonstrated with the government of Uruguay, but the President of the republic, (Aguirre,) while feigning a desire to do justice to the complaints of the empire, for which he held his subaltern agents responsible, in reality endeavored to support the republic of Paraguay.

This republic was at that time governed by Lopez II, who was a republican only in name. He was, in fact, the most immoral, the most tyrannical ruler in all America. He was, besides, very ambitious of military glory, and as soon as he became President (in appearance by election of the self-called National Congress, but in reality by heritage and his own will, as the only general of the republic) he imagined he could perform in La Plata the role which Napoleon III had for some time taken in Europe, viz, the maintenance of European equilibrium. For this end he made of the nation a regular military depot, and only waited for an opportunity to send forth his troops. He had, besides, accumulated an immense quantity of material for war, so that he was quite prepared not only to enter into a military contest, but to maintain it for a long time.

The hostile attitude of Brazil toward Uruguay furnished the President of Paraguay with the pretext he desired to forward his pretensions. After demanding, for the sake of form, of the representative of Brazil at Assumption (the capital) information in regard to the views of the imperial government, he sent to the latter, in the month of September, 1864, a declaration that he would not consent to the occupation by Brazilian troops, neither permanently nor temporarily, of any part whatever of the territory of Uruguay. . . .

The imperial government made a mistake in taking no notice of this declaration of the despot ; and, not receiving the satisfaction demanded of the government of Uruguay, invaded the territory of that republic. The Brazilian troops and those of General Flores, who held the open country, naturally united against the common enemy, and obtained their first victory in the taking by assault of the city of Paysandee. This alliance, made upon the field of battle, having been ratified by the imperial government, the united forces marched together upon the capital of the enemy,(Montevideo,) and obliged it to capitulate on the 20th of February, 1865.

The news of the invasion of Uruguay provoked on the part of Lopez an open act of hostility against Brazil. A steamer was expected belonging to a Brazilian company, and which did service between Rio Janeiro and the Brazilian province of Matto-Grosso, passing by the capital of Paraguay. When the boat arrived at Assumption—it was the Marquez de Olinda—it was seized by order of Lopez and most of the passengers made prisoners, among others a colonel who was on his way to take charge of the government of the province of Matto-Grosso, (November, 1864.)

This act excited great indignation in the empire, and an outcry from all parts of the country for punishment of the tyrant. The feeling was so general, that at the end of several weeks the number of the volunteers who responded to an appeal made by the Emperor to their patriotism was more than sufficient, and the government was obliged to decline further offers of service. Lopez then took possession of the province of Matto-Grosso. He was obliged to pass through the territory of the Argentine Republic in order to invade a second Brazilian province, Rio Grand de Sud, and, not having obtained permission, did so by force, commencing hostilities by the surprise and seizure of two ships of war. Thus a triple alliance was formed against Lopez, consisting of Brazil and the two republics, Argentine and Uruguayan. General Mitré, President of the Argentine Republic, was made chief in command of the allied armies.*

Although the tyrant had to struggle against all these powers, the war lasted five years, and was the most sanguinary that had ever been known in South America. In the first place, Lopez possessed, as we have said, formidable resources in the materials for war † he had collected. Then Paraguay, the principal theatre of operations, was admirably protected by numerous lagunes, water-courses, forests, and mountain-chains, while to these natural barriers were added extensive military constructions.

Brazil, which was the soul of the alliance, and which alone possessed a squadron, blockaded Paraguay from the commencement of the year 1865, while the allied armies assembled upon the territory of the Argentine Republic, in order to pass over the 200 leagues which separated them from the enemy's country.

In the month of June, 1865, the Brazilian squadron destroyed, in the naval contest of Riachuelo, the squadron of Paraguay, consisting of eight war-steamers, protected by floating batteries of earth.‡ Three months later the Paraguayan commander of a column of 10,000 men (the same which had invaded the province of the Rio Grande) capitulated in the city of Uruguayana, in the presence of the Emperor, who had undertaken in person to drive the enemy from this part of the empire.

In April, 1866, the allies passed the Parana, the frontier of the enemy. Several battles, among which should be mentioned that of the 24th of May at Tuyuty, (about 70,000 men were present,) distinguished the first period of the campaign in the enemy's country. The assault undertaken on the 23d of September, from the direction of Curupaity, against the terrible Humayta, (the Sebastopol of America, constructed upon a very sharp elbow of the river Paraguay,) failed completely, with great loss to the allied forces. The latter then undertook a siege of the fortress, which lasted two years.

The fall of Humayta (August, 1868) was secured only when the iron-

* The Brazilian army was commanded by General Osorio, and that of Uruguay by the President, General Flores.

† He commenced with an army of 80,000 men, in all respects perfectly equipped, and well distributed over the entire region of the war.

‡ The battle took place upon the waters of the Parana, near the mouth of the small river Riachuelo; hence the name of the contest. The Brazilian squadron was also composed of eight war-steamers of wood, the iron-clad vessels being still in course of construction. The victory was for a long time undecided, and there were several very exciting occurrences, among others the capture and recapture of a Brazilian sloop, the Parnahyba.

clad squadron of Brazil forced the passage of the river defended by this fortress; a passage which, in the beginning of the war, had been considered impracticable on account of the formidable batteries, the torpedoes, the chains, and the vessels sunken in the stream, all of which formed a powerful system of defense. The remains of the garrison of Humayta, (4,000 men,) in accordance with the orders of Lopez, refused to surrender, and fought ten days without intermission in the almost-island opposite the fortress, where they had taken refuge after being compelled to evacuate. This valiant and obedient garrison, deaf to the most honorable proposals of the allied commanders, ended by falling from exhaustion. Never was there a more bloody contest.

This obstacle surmounted, the Marquis of Caxias, placed at the head of the Brazilian troops after the reverse of Curupaity, and commander at this time of the allied forces, with the Brazilian squadron, also under his orders, proceeded toward the capital of the enemy, which could, however, be reached only by passing through the main body of the army of the tyrant, which had protected the city with new and important lines of defense. These had all been erected since the bloody battles of Itororo and of Avahy, (on the 8th and 11th of December, 1868,) and the assaults upon the camp of Lopez, at Lomas Valentinas, (on the 21st and 25th of December,) in which the Brazilian army alone lost a third of its most effective men. After repeated victories the allied armies made their triumphal entrance into the capital, (on the 1st of January, 1869,) which had been abandoned after the fall of Humayta. The Marquis of Caxias then left the army on account of illness, and was replaced by the nephew of the Emperor, the young Count d'Eu, who was also marshal of the empire. The count took by assault the new capital of the enemy, (the city of Pirebeburg,) then chased Lopez from the first chain of mountains in which he had taken refuge, destroyed the remainder of his army in the battle of Campo Grande, and finally pursued him to the extreme limits of the republic.

Lopez, whose men had been reduced to a few hundred, was surprised in his encampment on the 1st of March, 1870, by the Brazilian troops.* As soon as he perceived the enemy he mounted a horse and fled, while his companions fought desperately. As he was about to reach the edge of a dense forest, in which he hoped to save himself, the soldiers of the Brazilian cavalry fired upon him, preferring to kill him rather than allow him to escape. To say nothing of his never having conducted his troops personally into battle, Lopez had not even the courage to defend himself when attacked, and, like most tyrants, died the miserable death of a coward. With his decease ended the long struggle in which were sacrificed 200,000 Paraguayans, about 80,000 Brazilians, and 10,000 Argentines and Uruguayans. Brazil, besides, expended nearly two thousand millions of francs.

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* The last operations of the war with Paraguay was exclusively the work of the Brazilian army.

The gratitude of the Brazilian people to their sovereign, and of the imperial government to the troops and victorious generals, was manifested in an admirable manner. A sum of three millions of francs was collected by a national subscription to raise a statue to Dom Pedro, but the modest Emperor devoted this amount to the good of public instruction; the Marshal Caxias, already a marquis, was made a duke, (the only one in Brazil;) Count d'Eu, being already marshal of the army, was, upon his return to the capital of the empire, the object of brilliant ovations: the *fetes* celebrated by the city in his honor and in that of the army lasted three days, and cost about two millions of francs. On this occasion the Emperor expressed to the army his happiness and gratitude by embracing the commander and one of the soldiers of each battalion. Several of the generals received, with promotion in rank, titles of nobility; among others, General Osorio was successively made baron, viscount, count, and marquis (do Herval): he was also accorded an annual pension of about 20,000 francs, in addition to his pay as general of the army. General Camara, the conqueror of Lopez, was made viscount (de Pelotas), and also received a pension of 20,000 francs. To the officers of the volunteer corps the government accorded honorary promotion, and preference in the nomination to public employ; finally, every volunteer soldier (there were about 30,000) received the sum of 800 francs, besides a certain portion of land in the interior of Brazil.

IX.

The enormous sacrifices Brazil was forced to make to sustain the war, which lasted much longer than was at the beginning anticipated, determined the political party which came into power during the hostilities to propose to the Emperor to conclude peace before the fall of Lopez; but Dom Pedro under these circumstances manifested the most ardent patriotism and at the same time great political discernment. He never lost faith in the ultimate success of his arms, although the enemy employed every means of resistance the most unscrupulous despotism could invent under the vail of patriotism; he, moreover, understood better than any one else the importance of giving a severe lesson to Paraguay, this natural ally of the constant enemies of Brazil—the republics of South America. So strong was his conviction in this respect, that he would not hear of peace, and even went so far as to declare formally he would abdicate rather than parley with such a foe; affording thus an example of self-abnegation and patriotic energy worthy to be placed by the side of that given by Appius Claudius, (the blind,) who was not a king, it is true, but a member of the famous Roman senate, which, by its dignified bearing in the presence of misfortune, appeared to the messenger of Pyrrhus an assembly of kings. "I have for a long time," indignantly exclaimed the illustrious blind old man, "complained of the gods because they deprived me of sight, but now I thank them, and even regret that they did not make me deaf also, that I might not hear such disgraceful proposals. Our fathers thought not of peace under such circumstances; on the contrary, the greater the danger, the greater their heroism and perseverance. It is thus they became great!" The Emperor would no more make peace with Lopez than the Roman senate with the king of Epirus.

Another circumstance also proved both how much Dom Pedro had at heart the reparation of the affront to his country, and the entire confidence he had in final victory: After the reverse of Curupaity, he had confided the chief command of the Brazilian troops to the head of the conservative party, Marshal Caxias, a measure which was approved by the liberal ministry under Senator Zacarias. Some time after, the reciprocal confidence between the general and this body was disturbed to such a degree that both offered to resign; but the Emperor was able to produce a reconciliation, and thus to secure the judgment and skill of the general, which he deemed absolutely necessary for the success of the imperial arms. Still a certain opposition began to be manifest, both in the press and the chamber, by the minority of the liberal party, to the marshal, who was accused of being too slow in his military operations. This increased more and more, and even extended to the ministry; the latter shortly after, disagreeing with the Emperor in regard to the choice of a senator, (a choice exclusively reserved for the sovereign by the constitution,) again offered their resignation, which was this time accepted,

Dom Pedro was now obliged to choose between a new liberal ministry, which could inspire the confidence neither of the general-in-chief nor yet of those who were opposed to him, and a conservative ministry which would be willing to afford the marshal every possible means to secure the victory. These considerations decided the Emperor in favor of the latter, which was presided over by the Viscount de Itaborahy, who was obliged to dissolve the Chamber of Deputies for refusing to support him (July, 1868).

The conduct of the Emperor towards vanquished Paraguay proved that he had been animated by no feeling of hatred for that unhappy country; on the contrary, it afforded another evidence of his proverbial magnanimity, for he voluntarily pledged himself after the war to keep the country independent for ten years, on account of the feeble state to which it had been reduced.

X.

The war did not prevent the imperial government from taking all the administrative measures the circumstances would allow to increase the prosperity of the country. The navigation of the Amazon was opened to foreign nations; new lines of railroad were projected, and the construction of those which had been commenced was not allowed to be interrupted; in a word, progress continued with a firm and assured pace, and, except a slight increase in the rights of dower and of land and personal taxes, absolutely nothing indicated that the nation was engaged in a formidable contest. Commercial transactions received such an impulse that large fortunes were made as if by enchantment.

One fact is worthy of being recited: In the last year of the war, when the army and the squadron were reduced because the strength of the enemy was not as great, the custom-house revenue of Rio Janeiro (about 300,000 francs a day) was sufficient to cover the expense of the war; so that the campaign against Paraguay not only exhibited the patriotism, the strength, and the perseverance of the Brazilians, but also the immense resources of their country.

Peace concluded, the government, far from resting upon its laurels, employed every means to draw from the experience gained during the war knowledge that would be useful in the future, and render the country better able to meet with promptitude attacks from its turbulent neighbors or other nations. The leaders who had most distinguished themselves upon land and sea during the war were consulted as to the best measures for this end; and, in accordance with the information received from them, new iron-clad vessels were ordered, among which should be mentioned the frigate Independencia, still in course of construction at London, and one of the largest in the world;* the army was re-organized; the mode of recruiting by force, hitherto employed, was replaced by the system of conscription; corporal punishment, so derogatory to human dignity, was abolished, and the pay of the officers was increased a third.

Perhaps the most urgent need felt by the country after the war was the resupply of the farming population of this vast empire, relatively depopulated by the loss of a hundred thousand men, for the most part cultivators of the soil. The solution of this great problem depended for the most part, if not absolutely, upon the settlement of another important question, the abolition of slavery, which had for several years been a subject of especial solicitude with Dom Pedro, not only on account of his well-known ideas of philanthropy, but also because he was assured of what he constantly endeavored to convince his ministers, that all efforts to establish a current of emigration toward Brazil, such as that toward the United States, would be useless as long as slavery existed. Both the liberal and conservative party at last understood the necessity of immediate attention to this difficult and delicate question.

Abolitional ideas had for a long time in fact been entertained by philanthropic minds in Brazil. Several societies called "liberators" had been formed for the purpose of freeing a certain number of slaves each year. Many provincial and municipal associations of the empire followed this good example, and every day negroes were liberated by individual owners; in a word, the current of public opinion had become too strong to be arrested, and the Emperor, who rejoiced in the course events had taken, determined to seize the first opportunity of satisfy-

*This frigate costs 12,000,000 francs. Brazil now possesses twenty-five iron-clad vessels.

ing not only his own philosophical and benevolent views in this matter, but also the desires of a large portion of his people.

As soon as the war with Paraguay was ended he called the attention of the conservative minister (Itaborahy,) then at the head of governmental affairs, to the subject. The minister, although he did not believe in the sudden and radical enfranchisement such as had taken place in the United States, thought the children of slave parents should be freed, but he had not the courage to take the responsibility of maintaining this opinion in opposition to the numerous and wealthy planters, many of whom held seats in Parliament or were electors. He preferred to send his resignation to the Emperor, which was eagerly accepted. The minister who succeeded him was also obliged to retire at the end of four months on account of the opposition, more and more threatening, of the slaveholders. What was to be done? Wait until the liberal party, which had inscribed this reform upon their programme, came into power? But how was it possible to wait?

Under these circumstances the Emperor offered the ministry to the Viscount Rio Branco, a man well known on account of his political ability and an especial talent for conciliating unruly spirits. The viscount carried out, although not without great trouble, the views of the Emperor and the Brazilian nation, and on the 28th of September, 1871, was passed by the Parliament the law known under the name of the "free womb." This legislative act, which declared the children born of slave-women after that day to be free, and required the owner of the parents for a slight indemnity to maintain the children until the age of twenty, was received with indescribable enthusiasm by all Brazil, with the exception only of the slaveholders, who held their pecuniary interests above those of their country and of humanity. The government received from all the various corporations, political or civil, and the religious societies, benevolent or otherwise, the most ardent promises of support and warm congratulation. In this universal feeling of contentment the generous promoter of this wise law, Dom Pedro II, was not forgotten, although at the time absent from the country, as we shall see.

XI.

Dom Pedro had for a long time wished to visit Europe, but the accomplishment of his desire had been postponed, at one time by troubles at home, at another by differences with foreign nations, and when at last the country was in a condition to allow this excursion, much to be desired on account of relations with foreign powers, the Emperor commenced his journey by passing through the provinces of his own empire he had not yet visited, thus showing himself true to his especial maxim, *Brazil first of all.*

Not only did the victory over Paraguay, which insured external peace by affording sufficient proof to the turbulent neighbors of Brazil that war against her could only end to their disadvantage, and the interior order of the country not disturbed since 1848, seem especially opportune for the execution of this project of a voyage to Europe, but the health of the Empress required the journey.

According to the Brazilian constitution the sovereign cannot leave the country without permission of parliament, under pain of forfeiting the empire. Dom Pedro asked and obtained leave of absence for a year, and started for Europe in the month of May, 1871, under the name of Dom Pedro d'Alcantara, confiding the regency of the empire to his daughter, the Countess d'Eu. He sailed with the Empress and a suite of ten persons on board the English steamer which passes regularly between Rio de Janeiro and Southampton, for he would not spend a centime more than the allowance of a civil officer, which, by the way, is not great—2,000,000 francs a year. The entire population of Rio turned out to wish him a happy journey, and a speedy return. They collected upon the quay, in the windows facing the port, upon the roofs of the houses, on the islands of the bay, waving their handkerchiefs as he appeared, and filled the numerous small steamboats which were to escort for some distance the vessel containing the august travelers. These sincere and touching adieus showed how much the people loved their sovereign.

The first stopping place of the imperial tourists was Lisbon. Upon the arrival of the Emperor, Louis I, his nephew, came to meet him, and offered to suspend the rules of quarantine and conduct him immediately to his palace. Dom Pedro firmly determined to travel as a private gentleman, not only refused to accept this offer, but also to pass the four days of quarantine in a man-of-war the King placed at his disposal. He lodged therefore in the common lazaretto with all the passengers who had landed at Lisbon. He passed several days in the beautiful capital, and then went by rail to Spain, promising his royal nephew to pass a few days in Portugal on his return to Brazil. After Spain he visited France, England, Belgium, Germany, Switzerland, Austria, Italy, and Egypt. He took advantage of his journey to lay the foundations of several treaties of commerce and friendship, but particularly of extradition, which were afterwards consummated.

In these different countries, of which he knew as much as could be learned from written descriptions, Dom Pedro made a careful examination of the works of art, of science, and of industry, the schools, universities, and scientific societies, whose meetings he delighted to attend. He invited to his table distinguished men of all classes, and surprised more than one Diogenes in his tub. Everywhere and to everybody, he exhibited much more knowledge than is generally possessed by the heads of nations, and on his return to Brazil, honored with the most distinguished decorations the men of letters, arts, and science with whom he had been in relation. In certain charitable institutions and in the poor quarter of several large cities, he left substantial souvenirs of his visit.

Dom Pedro was decorated on this journey with the order of the garter, and also received diplomas from several learned societies, among which we may mention that of member of the natural history section of the French Institute, a deserved reward for his profound study of this branch of knowledge. In short, the journey was a success, and of great importance to Brazil, as the Emperor was enabled to refute the errors that superficial or malevolent writers had spread all over Europe in regard to the country.*

Dom Pedro quitted Europe with the firm determination to return at some future time, and visit the countries of the north as well as Turkey.

XII.

The return of Dom Pedro to Brazil gave the people another opportunity of showing their attachment, by an enthusiastic welcome, and a brilliant reception at the capital. One of his first acts was to abolish the system of vassalage which had descended from the ancient kings of Portugal. Then he hastened to introduce every useful art and custom he had seen abroad compatible with the climate, institutions, and national habits of the country. The capital in this way was embellished with numerous erections, which at the same time responded to the requirements of public comfort. †

Brazil was then united by the telegraph with Europe, the United States, and the republics of La Plata. Several other works of public interest, such as the construction of new railways and the opening of new roads, &c., were undertaken or received new impulse from the government. For the better success of his plans for material improvement, Dom Pedro nominated as minister of public works, of commerce, and of agriculture the Senator Viscount de Itaúna, who had accompanied him on his voyage to Europe, and was, in consequence, the best interpreter of the desires of the Emperor.

In political and intellectual affairs there was radical reform, especially in the reorganization of primary schools, of higher schools, and the revision of the electoral law.

The solicitude Dom Pedro had always felt in regard to public instruction, proves conclusively how entirely he was convinced that it is the

* It may be well to give here the opinion of Professor Agassiz in regard to these errors: "Like every country," he says, "struggling for recognition among the self-reliant nations of the world, Brazil has to contend with the prejudiced reports of a floating foreign population, indifferent to the welfare of the land they temporarily inhabit, and whose appreciations are mainly influenced by private interest. It is much to be regretted that the government has not thought it worth while to take decided measures to correct the erroneous impressions current abroad concerning its administration, and that its diplomatic agents do so little to circulate truthful and authoritative statements of their domestic concerns."—(A Journey in Brazil, by Professor and Mrs. Agassiz.)

† Among the public constructions at Rio especially remarkable, are the foundling asylum, the hospital of Mercy, the military school, the primary schools, the exchange, the public treasury.

condition *sine qua non* of all real and lasting progress. It is, therefore, not surprising that during his journey his attention should have been especially directed to this branch of public administration. After adopting the methods and programmes of study which seemed to him the best, he caused a number of really palatial buildings to be erected, with spacious gardens attached, to be used as public schools for children of both sexes; and in order to render study agreeable, the luxury and provisions for comfort in these establishments were so great as to be condemned as extravagance by those opposed to the projects of the Emperor.

In the high schools, reform was introduced in the regulation of examinations. These were rendered so much more difficult as to excite the manifest hostility of the students; but the increased rigor was really necessary, as the diplomas conferred by the scientific corporations had ceased to be regarded with much confidence.

The central school was reorganized and converted into a polytechnic institution, similar to the Belgian schools for engineers. Lastly, a school of mines was formed in the province of Minas, the richest in precious minerals, and now it is proposed to found at Rio a university, with due consideration, however, for the faculties of law and medicine existing in the provinces.

The reform of the electoral law is one of the greatest benefits Brazil has received from the very hand, so to say, of the present Emperor. The old law was full of flaws, which might allow a party in power to remain so continually, were it not for the prerogatives accorded the Emperor by the constitution. No party at the head of the administration had desired to reform this law, precisely because of the advantage to be drawn from its defects, but once in the opposition, there was no want of condemnation of the frauds and violence committed by the agents and friends of the government during the elections.

The greatest inconveniences resulting from this defective law were, on the one hand, the impossibility of knowing whether the parliamentary majority represented really the opinion of the people, and on the other the want of any security that the minority would be represented. Also, every dissolution of the houses of parliament was followed by a unanimous chamber, evidently the creation of the minister; and even if this had not the general support, it could always exercise great influence upon legislative decisions, because of its power over a large number of public functionaries; that is to say, on account of the number of public offices at its disposal.

For the purpose not only of putting an end to the complaints of parties not in power, but also and principally to govern in accordance with the real desires of the nation—the first duty of every honest government—Dom Pedro determined to reform the electoral law, and on the occasion of the opening of parliament in 1874, entered into a formal engagement to prevent, in the future, electoral abuses.

The liberal party desired election by one degree, that is, direct election; but the constitution positively required election by two degrees, that is, indirect. This was an insurmountable obstacle to the Emperor, for he knew that too frequent alteration of the organic laws of a country ends in political disorganization. He therefore confined his attention to such changes in the old system as would render parliament more independent of the government. Among the improvements of the new law was the decree that the holding of the office of representative was incompatible with the tenure of any other charge remunerated by the state, and that the government could not nominate any deputy or senator to an office six months before or after the elections. Should this loyal attempt at reform by the Emperor be unsuccessful, we are convinced he would propose to the people to change the constitution, rather than have the national vote continually misconstrued.

XIII.

Almost immediately after the return of Dom Pedro to Brazil, toward the end of the year 1872, occurred an event known under the name of the *religious question*, of which we must give a brief account, for, although much to be regretted, it gave proof of the moderation of the Brazilian monarch, and his respect for the national institutions.

The bishop of Pernambuco, (Mgr. Vital de Oliveira,) who had received his religious education at Rome, where he had been nominated to office at the age of 28, forgetting the maxim of Talleyrand, "*above all, no zeal*," came to Brazil with the predetermination, it would seem, to suppress Free Masonry in his diocese, which had not been attempted by the ten preceding bishops nor by the primate of Brazil; for they knew that, under the form in which it existed in the empire, it was not hostile to the Catholic religion. The conduct of the young bishop, whom the Pope at the time called *too hot-headed*, is so extraordinary that we transcribe literally that document, the cause of the disturbance which followed, in order that the reader may judge of it for himself.

On the 28th of December, 1872, Mgr. Vital de Oliveira sent to the vicar of the parish of Saint Antoine (at Pernambuco) an order conceived as follows: "It has come to our knowledge that Doctor Costa Ribeiro, *well known as a Free Mason*, is a member of the fraternity of the Très Saint Sacrement of this parish; and as the initiated of the order of Masonry are under the ban of high excommunication imposed upon them by several of the Popes, we order you, without delay, to see the judge of the fraternity, and command him in our name to exhort, kindly but instantly, the Brother Costa Ribeiro to abjure this sect condemned by the church. If, unhappily, he refuse to retract, let him be immediately expelled from the fraternity, inasmuch as excommunicants are excluded from it by ecclesiastical institutions. *Let the same course be pursued with regard to any other Free Mason who may be a member not only of this, but of any other fraternity in the parish.*"

(Signed, etc.)

The fraternity, in united council, decided to *beseech* the bishop to withdraw this order as being doubly illegal. It required what was in fact contrary to the organic rules of the fraternity, which authorized no expulsion of its members on account of being Masons, and contrary also to the constitution of Brazil, which required (article 102, § 14) that apostolic letters and other ecclesiastical mandates must receive the confirmation of the government before they could be carried into execution. Now, the order condemning Masonry had not been authorised with the imperial seal; besides, the fraternities were not only religious but civil orders, and in the latter capacity did not come under the authority of the church. An order such as that of the bishop of Pernambuco had never before been given by any of the bishops of the empire, Masonry in Brazil having the same legal title to existence as any other society whatever.

Notwithstanding these considerations, which the fraternity endeavored to impress upon the bishop, the latter persisted in his design, and ended by pronouncing the sentence of interdiction, by which the members of the fraternity were forbidden to appear in any religious ceremony whatever with the insignia of the society. The fraternity entreated the bishop in vain to withdraw this severe and illegal restriction; they then carried it, as an abuse, to the crown, founding their appeal upon the requirement of the constitution which had been disregarded.

The government, wishing to act with prudence and justice, consulted the council of state, which was of the opinion that the bishop had abused his authority in requiring the expulsion of the masonic members of the fraternity, and in pronouncing against the society the sentence of interdiction, inasmuch as the organic laws of the fraternity were under the supervision of the civil authority, the bishop having only the right to approve and control those appertaining to religious matters. In consequence of this decision the government ordered the bishop to withdraw, within a month, the sentence of interdiction. The bishop not only refused obedience himself to this requirement, but enjoined the same on his vicars, under threat of suspension *ex informata conscientia*, a threat he immediately executed upon one of them who merely seemed irresolute. He besides declared in a public address that he had not taken the demands of the constitution into account, as he recognized no higher authority than that of the church. This act of real rebellion obliged the government to prosecute the bishop for disobedience to the laws, but this was not done without again consulting the council of state, this time in full conclave. An embassador was at the same time sent to Rome to demand the support of the Pope against the refractory bishop, which proves conclusively that the imperial government desired to remain on good terms with the religious power. The Emperor was, besides, quite ready to remit any penalty the tribunal might impose upon the bishop, if the Pope induced the prelate to withdraw the interdiction.

The Pope, having probably been made to understand this, wrote a letter to the bishop expressing disapproval of his conduct and ordering him to withdraw the interdiction, but the prelate did not obey, under the pretext that the Pope had been misinformed in regard to the matter. The prosecution continued and the bishop was condemned to four years of hard labor, but the Emperor hastened to commute this punishment to four years of imprisonment.

During the prosecution the bishop of Para, following the conduct of his colleague of Pernambuco, was subjected to the like process. The affair then assumed a violent character both in the press and in parliament, where, however, the majority supported the government. The bishop from his prison—a palace situated on a beautiful fortified peninsula opposite Rio, in which he moved freely and was allowed to see any one who wished to visit him, and was treated like a prince—succeeded, by the intervention of ecclesiastical agents, in exciting the peasants of his diocese to a rebellion, happily soon repressed.

Notwithstanding the evident connivance of the bishop with these disturbances, the government forbore any further prosecution of him, in order to spare the Emperor the pain of seeing this high functionary condemned to more severe punishment. We can readily understand this feeling in a monarch, raised in the Catholic religion, with Catholic subjects, and who had taken the oath on ascending the throne to maintain the Catholic religion, which is the religion of State. Furthermore, Dom Pedro did not allow the term of imprisonment imposed by the high court of justice for the bishops to expire, but pardoned them at the end of two years. To this act of clemency the Pope responded by removing the interdiction pronounced by the bishops against the fraternities, and religious peace was restored to the empire.

XIV.

During the legislative session of 1875, Dom Pedro, taking advantage of the tranquillity of the country at home and fearing no trouble from abroad, demanded and obtained from parliament a leave of eighteen months. His purpose was to complete the tour commenced in 1871, and to visit the universal exposition held that year in Philadelphia, (United States of America.) Foreseeing this long absence, Dom Pedro had, after the retirement of the minister Rio Branco, (June, 1875,) nominated as his successor the old Marshal Duke de Caxias, who had twice been president of the cabinet, and who enjoyed a high reputation, well merited by his victories in Paraguay and over the enemies of the internal peace of the country. The duke had as colleague in the minister of foreign affairs the Baron Cotegipe, well known to possess an amount of energy, quite uncommon among Brazilian statesmen, especially displayed during the hostilities with the neighboring republics.

Having thus confided the government of his empire to a ministry of tried men and to the regency of the princess, the successor to the throne, Dom Pedro left for the United States the latter part of last March, and at the moment of writing we know that he has received a most flattering welcome from the country of Washington and Franklin, not only on the part of public authorities, (although he desired to preserve a rigorous *incognito*,) but also by the press and the people of that powerful republic. We are sure that Dom Pedro is convinced by this reception of the sincerity—he has, however, never doubted—of the desire of the great republics of North America to maintain cordial relations with the great empire of South America, a policy perfectly in unison with the spirit of the people and the proud reserve of one of their most able representatives, Monroe, who repudiated all European intervention in America, wishing the continent to belong to Americans alone.

From the United States Dom Pedro took passage for Europe, where there is no doubt as cordial a reception awaits him as he received in that country five years ago.

XV.

A few words before closing this sketch in regard to the personal characteristics of Dom Pedro, both as a man and as a sovereign.

In respect to *physique*, he is tall, well formed, with light hair and complexion; he has blue eyes, a benevolent expression, and wears a full-grown beard, which is very gray, much more so than his hair; his whole appearance is attractive and his manner sympathetic; he will be fifty-one years of age next December.

Dom Pedro's activity is extraordinary. He rises at 6 o'clock, reads certain news journals, while his secretary looks over others, and marks passages worthy of consideration, attends to business until half past 9, breakfasts rapidly,* then gives audience to the public; after which he generally visits the schools, arsenals, fortresses, or attends a session of a scientific society, &c.† He dines at 5, again gives audience to the people, and then resumes business,‡ if he does not go to the theater, (of which he is very fond,) to a concert, a ball, or some private entertainment. He never retires before midnight.

When visiting the establishments for instruction, whether private or belonging to the state, in the capital or in the provinces, he assists in the examination of the pupils and in the distribution of prizes, and makes note on these occasions of the name, family, and place of birth

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* He never remains more than half an hour at breakfast, nor at dinner, and has at his table all his personal attendants, who are on duty for a week.

† Dom Pedro never fails to be present at the reunions of the Brazilian Institution of History and Geography, of which he is the honorary president.

‡ He has a library, and a very complete laboratory for natural and physical science. Besides the study of these branches, as well as of political and moral science, he is much interested in ancient literature. In a synagogue in London, during his visit in 1871, he delighted the rabbins by translating a page of their Hebrew Bible.

of those who distinguish themselves in their studies. More than one thus noticed has afterward found in the Emperor a powerful protector.*

Dom Pedro not only encourages letters and the arts, he also renders important aid to industrial societies of general utility, either from his own purse, by the purchase of shares, or by demanding subsidy for them from the legislative bodies.†

He presides twice a week at the council of state. The session commences at 9 o'clock in the evening, and lasts sometimes until 1 in the morning. Each minister gives an account in his presence of all the matters in his department requiring the imperial signature; the Emperor listens with attention, and occasionally asks for some explanation. If the matter is of importance, especially if it touches the rights or the purses of the citizens, he will not allow a decision on the same day, but takes time to study the subject carefully, giving his opinion at the next session. If it is a radical innovation he employs a longer time in examining all its details, consults the council of state, and adopts it at last only if convinced that it is really and intelligently desired, and will be of profit to the people; for his long experience in the government of men has taught him that reform must be carefully considered, must be opportune and very evidently beneficial before it is adopted, in order that progress may be made. In this respect he is a liberal conservative, as every head of a nation should be who desires to respect the laws and at the same time advance civilization.

One would suppose from this active interference of the Emperor in the affairs of state, that the ministry exercises but little power. But this is not the case, for the Emperor has for the constitution, and for the public offices it creates, an almost religious respect. It is sufficient to say that he has not once during his long reign made use of the veto power given him by the constitution. He has never forced his own wishes upon any of his ministers; he leaves them entire freedom of action. But this very respect for the laws of the nation, as well as his own experience, has taught him the necessity of exercising his sovereign attributes, which he does, taking counsel only of his own conscience.

This loyal conduct, this benevolent interference on the part of the sovereign in the affairs of the country, has nevertheless been attacked

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* We are glad to give the following example: When M. Carlos Gomes, a Brazilian composer, after completing his studies in the school of fine arts at Rio and at Rome played for the first time, in the Brazilian capital, his beautiful opera *Le Guarany*, which had been very successful in Italy and London, he was summoned to the imperial box and warmly congratulated by the Emperor, who gave him at the same time the diploma and the badge of an officer of the order of the Rose set in diamonds.

† There exist in Brazil not less than eighteen lines of steamboats, supplied by the state, representing a value of 9,000,750 francs a year, without counting 568,000 francs contributed annually to the United States and Brazil Mail Steamship Company, whose vessels run every month between Rio and the United States, stopping at several Brazilian ports. As to the railroad lines, we know they have nearly all a security of 7 per cent.

as unconstitutional, as too personal a government. Those who pretend that the control of a nation should be left exclusively to the ministers and parliamentary majorities, rest upon the celebrated maxim: "*The constitutional king reigns, but does not govern.*" This is not the place to discuss this important question, but as to the maxim we cannot refrain from declaring, with Guizot, that it has no solid foundation. If M. Thiers uttered it, when in the opposition, it is very certain he would not defend it to-day, since his experience at the head of the French nation. It was the constitution of England, which in some sort deprives the sovereign of political action by the existence of a constituent and all powerful parliament, which led him to make this statement. But even with such a constitution, the distinction, as made by the Emperor between the attributes of the head of the nation, of its ministers, and of the national parliament, is absolute, as M. Thiers himself proved by his conduct in the constituent assembly of Versailles, during his government of the country from 1871 to 1873. It is, moreover, very easy to show the nonsense of the remark by substituting for the word *reign* its true significance, as given by the good Lettré, in his remarkable dictionary: "To reign," he says, "is to *govern* a state under the title of king, queen, emperor, elector, prince, or duke." Now, is it not nonsense to say the king governs, but does not govern?

The maxim, moreover, is not in accordance with the Brazilian constitution, which confers upon the sovereign not only control over the political powers governing the nation, but also especial attributes to be exercised by him exclusively. The accusation therefore that the Emperor is illegal in his personal government is without foundation.

We have seen that Dom Pedro gives audience to the public twice a day. On these occasions he exhibits the qualities of a truly liberal sovereign, and shows that he cares as much for the interests of his Brazilian family as for his own. In fact, he receives every one, foreigners or his own people, with affability and kindness, pressing the hand of those he regards especially. If an artist or a savant presents himself, Dom Pedro does not allow him to depart without some conversation upon his especial pursuit; if one of his acquaintances, he inquires with interest for the health of the different members of his family and interchanges with him some familiar and pleasant remarks. To claimants he has become somewhat reserved in manner on account of the great number who have imposed upon his kindness, and also because he does not wish to encroach upon the attributes of his ministers. Still, he listens with patience and attention; making from time to time an objection, or giving counsel; but he does not trouble the ministers with their pretensions, unless justice, equity, or benevolence require. If a complaint is made to him either from subaltern officials, who are very apt to suppose injustice has been done when they have not been promoted fast enough to suit their supposed deserts, from a disappointed office-seeker, or from any one whatever, Dom Pedro takes the trouble to inquire into and discuss the cause of his discontent. He endeavors to reconcile as much as possible the duties his political position impose upon him with his own inclinations, which always lead him to clemency and benevolence. Thus every year, on the occasion of certain religious, national, and dynamic festivals, he pardons the condemned and the criminals.

Although the penal law of Brazil authorizes the punishment of death, it was very seldom used in the commencement of his reign, and has not once been imposed during the last twenty years. What Dom Pedro has most at heart, is the manner in which justice is administered in his empire.* Thus one day, when a complainant had the audacity to tell him that one of his ministers had done him an injustice, he answered with some asperity, "My ministers never do an injustice." But in a moment resuming his natural benevolence, he added, "I will examine into your affair," and the next day reparation was made, the case being one of the few not without foundation.

The following incident in the life of Dom Pedro shows how ready he is to pardon offenses even against himself personally. A young lawyer of talent, desiring probably to attract the attention of the controlling minds of the country, wrote a pamphlet against the Emperor and all the house of Bragance, in language much too violent to be sincere; nevertheless, he became later successively a deputy, a minister, a councilor of state, a senator for life, and received a title of nobility. There was a cry of corruption on account of his advancement from the opponents of the Emperor, although he had retracted the substance of his pamphlet, and did not enter into the various offices until long after its publication. The truth is, he owes the position he to-day occupies to his real talent and to the magnanimity of his sovereign, who would not place the least obstacle in the way of his elevation, especially after his retraction, and since he devoted his talents to the service of his country, instead of employing them to defame her institutions and her rulers.

As to the liberality of the Brazilian monarch, it is manifested in various ways: sometimes by general almsgiving, (he causes several hundreds of centimes to be distributed to the poor every Saturday,) sometimes by especial donations, either voluntary† or by request, some-

* The government of the United States rendered homage to this spirit of justice in Dom Pedro, as well as to his wisdom, in electing him one of the arbitrators in the celebrated *Alabama* question. The monarch was represented at the tribunal of arbitration which met at Geneva, by the Viscount Itajuba, former professor of law in Brazil, and at present embassador of the empire at Paris.

† The following incident, recounted by the person benefited, shows the delicacy which clothes the acts of generosity of Dom Pedro. During an excursion into the interior of the country, where the hospitality of patriarchal times still prevails,* the Emperor was received by the principal resident-citizen of the place, a very respectable man, with whom he remained several days on account of his health. During his visit

*In some of the rural districts of Brazil, travelers are entertained gratuitously by the landholders, many of whom always have a large bell rung a quarter of an hour before every meal, in order to invite passers-by to take a place at their table.

times in annual pensions to certain meritorious persons, and frequently in sums of money given for the education of promising youth, often large enough to allow them to prosecute their studies in Europe.

It is an edifying proof of his religious feelings and of his Christian humility, that every year on holy Friday he washes publicly the feet of the poor in the imperial chapel, and that during the procession of the *Corpus Christi* he assists in carrying the dais throughout the ceremony.

The qualities we have noticed are sufficiently indicative of what Dom Pedro is in private; it is hardly necessary to say that he is an excellent husband and model father. The Empress, his faithful companion since 1843, is an admirable woman, a providence to the poor and the orphan; to know her many virtues and not love her is impossible. The heiress presumptive to the throne, the only child left him, has received a careful education, befitting her rank and the office she will assume in the empire. Her political instruction, promoted by several European tours, especially in England, where she seemed to seek in Queen Victoria an example for future imitation, is the exclusive charge of her august father. Her first essay in the art of government, four years ago, gave great satisfaction and promised well for the future. As she is now again in charge of the empire, Dom Pedro can travel without care, as he knows the love of the Brazilian people for their future Empress is as great and as sincere as that for their present Emperor.

CONCLUSION.

When we look back over the reign of Dom Pedro, and compare the Brazil of 1831, the time of the ascension to the throne by the present Emperor, when the national wealth was, so to say, insignificant, when the existence even of society was menaced by anarchy, when there were almost no means of communication with the interior, with the Brazil of to-day, taking into consideration its commerce and agricultural prosperity,* its numerous coast and river steamboats, its railroads and telegraph lines, passing through regions of country then occupied by virginal forests; its educational institutions of every degree, and its powerful means of defense—when we remember that these two periods are separated only by an interval of forty years, and reflect upon the immense progress which has been made in this comparatively short space of time, represented by the words riches, tranquility, respect, happiness—we have cause to be astonished, and to ask if all this is the work of a single man.

he learned confidentially that his host was in a bad financial condition, and that he knew not how to obtain the means to meet a large debt soon requiring payment. Dom Pedro, having assured himself secretly that he had been correctly informed, said to his host when the moment came to take leave of him, "You have forgotten to put away an important paper I have seen in the drawer of the bureau of the room I have occupied." It was the receipt of the creditor of his host.

* In 1831 the revenue of Brazil was hardly forty millions of francs; now it is over ten hundred millions.

It is true these great things have not been accomplished exclusively by the present Emperor of Brazil; but, as permanent head of the government, the credit of them for the most part, of right, belongs to him. It is at his instigation that important measures of the administration have been undertaken; it is he who has the right to approve or reject the projects of reform; he, in short, who has selected the men who have aided him in the realization of his philosophical ideal of prosperity for his people. The Brazilians render him full justice, and thank him for the position their country occupies among civilized nations.

Almost as large as Europe, and by nature the richest country in the world, Brazil is, in fact, the most prosperous and the most powerful state of South America, and stands next to the United States in the whole of the western hemisphere. "Should her moral and intellectual endowments," said the eminent naturalist Agassiz, "grow into harmony with her wonderful natural beauty and wealth, the world will not have seen a fairer land." *

We do not for an instant doubt the condition of this prophecy will be fulfilled, particularly if the future governors of the empire take as model the wise administration of Dom Pedro.

It is a custom of biographers to compare the persons they describe with others of the same rank who have points in common, but we find no monarch now upon the throne, although several have reigned at various historical epochs, with whom we can compare the Emperor of Brazil.

If we go back to antiquity he may be placed side by side with the best of the Roman Emperors. Like Vespasian, he established order in an empire disorganized by factions and the machinations of ambitious men, and gave an impulse to the arts and sciences. In this respect he also resembles Augustus, but unlike him had no supporters such as Mecænas and Agrippa. His noble qualities of heart give him the right to say with Titus, "The day passed without an opportunity for a good deed is a day lost." He is not a warrior like Trajan, but when his country was invaded he went in person to meet the enemy, and forced him to capitulate, and if the Roman emperor refused to allow a column to be erected to record his victories, the Brazilian Emperor declined the statue his people wished to raise in his honor after the war of Paraguay. As to the rest, they were equal in love of justice and respect for the laws.

Dom Pedro appreciated as did Hadrien the inestimable benefit of peace to human prosperity. The virtues and the modesty of Antony the Pious were not greater than those of the Brazilian monarch; and by his clemency toward others and his severe judgment of himself, he deserves to be placed by the side of Marcus Aurelius, the philosopher.

In the middle ages we can think of no sovereign who can justly be compared with Dom Pedro in regard to the organization and adminis-

* Work already cited.

tration of government, in interest for the education of youth, in simplicity of manner and personal activity, except Charlemagne, who, while governing with his own eye the empire extending from the Ebre to the Baltic, superintended the planting of the fruit-trees on his farms and the number of eggs to be sold, while he devoted his evenings to study.

Finally, in modern times we can mention as his equal only Peter the Great, who had also to recreate his kingdom under every species of opposition.

But these comparisons with sovereigns who reigned before the rights of men were acknowledged, and who knew no other law than their own will, with the head of a modern nation accustomed to govern itself and recognizing no power greater than its own, are necessarily defective and incomplete, although they serve to place in stronger light the personal and social virtues of the monarch. We should rather seek among constitutional rulers the equal of Dom Pedro in humanity and patriotism, as well as in his comprehension and application of parliamentary regime. On this ground there can be no hesitation in selecting the sovereign who was the preceptor of the present Emperor of Brazil in the difficult art of governing a free people. We speak of Leopold I, of Belgium, whom history has already surnamed *the model constitutional king.* In our opinion the pupil has quite equalled the master; posterity will be the judge.

KINETIC THEORIES OF GRAVITATION.

BY WILLIAM B. TAYLOR, *of Washington.*

"Non fingendum, aut excogitandum, sed inveniendum quid Natura faciat aut ferat."—BACON.

"Causas rerum naturalium non plures admitti debere, quam quæ et *veræ sint*, et earum phænomenis explicandis *sufficiant*."—NEWTON.

Ever since the grand demonstration by Newton in 1682, that the moon is a falling body, observing precisely the same law of decline from a rectilinear path as the cannon-ball, and that it is therefore under the dominion of the same force, an eager and unceasing desire has been manifested to discover an antecedent or origin of this universal tendency of matter.

Even before this date, or in 1671, the ingenious Dr. Robert Hooke had endeavored to trace the cause of gravitative fall to the external action of waves in a surrounding medium. He appears to have been led to this reflection by observing that small bodies floating on the surface of agitated water collected toward the center of disturbance or the origin of the waves.*

Newton himself, as is well known, speculated on this subject, and some years before arriving at his great generalization, he threw out a suggestion as to the cause of *terrestrial* gravity in a letter to Mr. Boyle. As connected with this speculation, it may be well to recur to Newton's still earlier statement of his conceptions in regard to the nature and action of the æther. In a letter to Mr. Henry Oldenburg, secretary of the Royal Society of London, in January, 1675–6, he thus unfolds the hypothesis:

"First, it is to be supposed therein that there is an ætherial medium, much of the same constitution with air, but far rarer, subtiler, and more strongly elastic. But it is not to be supposed that this medium is of one uniform matter, but composed partly of the main phlegmatic body of the æther, partly of other various ætherial spirits, much after the manner that air is compounded of the phlegmatic body of air intermixed with various vapors and exhalations; for the electric and magnetic effluvia and the gravitating principle seem to argue such variety. Perhaps the whole frame of nature may be nothing but various contextures of some certain ætherial spirits or vapors, condensed as it were by pre-

* Posthumous Works of Robert Hooke, edited by Richard Waller. London, 1705, pp. xiv, and 184.

cipitation, much after the manner that vapors are condensed into water. . . . . *Thus perhaps may all things be originated from æther.* . . ."

"In the second place, it is to be supposed that the æther is a vibrating medium like air, only the vibrations far more swift and minute; those of air made by a man's ordinary voice succeeding one another at more than half a foot or a foot distance, but those of æther at a less distance than the hundred-thousandth of an inch. And as in air the vibrations are some larger than others, but yet all equally swift, (for in a ring of bells the sound of every tone is heard at two or three miles distance in the same order that the bells are struck,) so I suppose the ætherial vibrations differ in bigness but not in swiftness."*

Newton had in 1672 controverted the supposed opposition of his views to the action of the æther by answering: "The objector's hypothesis as to the fundamental part of it is not against me. That fundamental supposition is, 'That the parts of bodies when briskly agitated do excite vibrations in the æther, which are propagated every way from those bodies in straight lines, and cause a sensation of light by beating and dashing against the bottom of the eye; something after the manner that vibrations of the air cause a sensation of sound by beating against the organ of hearing.' Now the most free and natural application of this hypothesis to the solution of phenomena I take to be this: That the agitated parts of bodies, according to their several sizes, figures, and motions, do excite vibrations in the æther of various depths or bignesses, which being promiscuously propagated through that medium to our eyes, effect in us a sensation of light of a white color; but if by any means those of unequal bigness be separated from one another, the largest beget a sensation of a red color, the least or shortest of a deep violet, and the intermediate ones of intermediate colors, much after the manner that bodies, according to their several sizes, shapes, and motions, excite vibrations in the air of various bignesses, which according to those bignesses make several tones in sound; that the largest vibrations are best able to overcome the resistance of a refracting superficies, and so break through it with the least refraction; whence the vibrations of several bignesses, that is the rays of several colors which are blended together in light, must be parted from one another by refraction, and so cause the phenomena of prisms and other refracting substances; and that it depends on the thickness of a thin transparent plate or bubble whether a vibration shall be reflected at its further superficies or transmitted; so that, according to the number of vibrations interceding the two superficies, they may be reflected or transmitted for many successive thicknesses. And since the vibrations which make blue and violet are supposed shorter than those which make red and yellow, they must be reflected at a less thickness of the plate, which is sufficient to explicate all the ordinary phenomena of those plates or bubbles, and

* History of the Royal Society of London, by Thomas Birch, 1757, 4 vols. quarto, vol. iii, pp. 249–251.

also of all natural bodies, whose parts are like so many fragments of such plates. These seem to be most plain, genuine, and necessary conditions of this hypothesis. And they agree so justly with my theory, that if the animadversor think fit to apply them, he need not on that account apprehend a divorce from it."*

This passage is interesting as being the earliest presentation of a theory of color, now universally adopted. The same views were repeated as a suggestion, some forty-five years later, in the second edition of his treatise on "Optics."†

In his "Letter to the Hon. Mr. Boyle," dated February 28, 1678–9, (about six years later,) Newton, after proposing as an explanation of the phenomena of cohesion, chemical affinity, &c., the "supposition" that an exceedingly elastic subtile ætherial substance is diffused through all places and bodies, but much rarer within and near gross bodies than beyond them, adds toward the conclusion of his letter: "I shall set down one conjecture more, which came into my mind now as I was writing this letter: it is about the cause of gravity. For this end I will suppose æther to consist of parts differing from one another in subtilty by indefinite degrees, . . . in such a manner that from the top of the air to the surface of the earth, and again from the surface of the earth to the center thereof, the æther is insensibly finer and finer. Imagine now any body suspended in the air or lying on the earth, and the æther being by the hypothesis grosser in the pores which are in the upper parts of the body than in those which are in the lower parts, and that grosser æther being less apt to be lodged in those pores than the finer æther below, it will endeavor to get out, and give way to the finer æther below, which cannot be without the bodies descending to make room above for it to go into. From this supposed gradual subtilty of the parts of the æther, some things above might be further illustrated and made more intelligible. . . . For my own part, I have so little fancy to things of this nature, that had not your encouragement moved me to it, I should never I think have thus far set pen to paper about them."‡ It will be seen from the above that Newton had not at this time (only three years before the crowning epoch of his life) extended his conception of "gravity" to the outlying universe.

Fourteen years later—a decade after his culminating work—this topic was again incidentally touched upon by Newton in four letters addressed to Doctor Bentley, "containing some arguments in proof of a Deity." In his second letter, dated January 17, 1692–3, he says in reply to one from Bentley: "You sometimes speak of gravity as essential and inherent to matter. Pray do not ascribe that notion to me, for the

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* Philosophical Transactions of the Royal Society; November 18, 1672. No. 88, vol. vii, p. 5088.

† Newton's Optics. Second edition, 1777. Book iii, appendix. Query 13.

‡ The Works of Isaac Newton, edited by Samuel Horsley: In 5 vols., quarto. Vol. iv, pp. 385-394.

cause of gravity is what I do not pretend to know, and therefore would take more time to consider of it."*

In his third letter, dated February 25, 1692–3, he expresses himself somewhat less guardedly thus: "It is inconceivable that inanimate brute matter should, without the mediation of something else which is not material, operate upon and affect other matter, without mutual contact, as it must do if gravitation in the sense of Epicurus be essential and inherent in it. And this is one reason why I desired you would not ascribe 'innate gravity' to me. That gravity should be innate, inherent, and essential to matter, so that one body may act upon another at a distance, through a vacuum, without the mediation of anything else, by and through which their action and force may be conveyed from one to another, is to me so great an absurdity, that I believe no man who has in philosophical matters a competent faculty of thinking can ever fall into it. Gravity must be caused by an agent acting constantly according to certain laws; but whether this agent be material or immaterial, I have left to the consideration of my readers."†

At the conclusion of the third book of his *Principia*, Newton remarks: "Hitherto I have not been able to discover the cause of those properties of gravity from phenomena, and I frame no hypothesis; for whatever is not deduced from the phenomona is to be called an hypothesis. . . . To us it is enough that gravity does really exist, and act according to the laws which we have explained."

Still twenty-five years later than the date of these oft-quoted Bentley letters, Newton again recurred to the subject in an appendix to the second edition of his "Optics," published in 1717. After suggesting that the chromatic dispersion of luminous rays by refraction might be due to varying wave-lengths of an all-pervading "ætherial medium," (as previously referred to,) he asks: "Is not this medium much rarer within the dense bodies of the sun, stars, planets, and comets, than in the empty celestial spaces between them? And in passing from them to greater distances, doth it not grow denser and denser perpetually, and thereby cause the gravity of those great bodies toward one another, and of their parts toward bodies; every body endeavoring to go from the denser parts of the medium toward the rarer? . . . And though this increase of density may at great distances be exceeding slow, yet if the elastic force of this medium be exceeding great, it may suffice to impel bodies from the denser parts of the medium toward the rarer, with all that power which we call gravity."‡

The intellectual spirit of the age in which "gravitation" was established was one of strong reaction from the previous metaphysical sway of "occult qualities;" and that the above crude suggestion (perhaps offered too much in deference to that spirit) by no means satisfied the judgment of Newton, is shown by his subsequent inclination to dispense

* Works, edited by Horsley, vol. iv, p. 437.

† Works, *ut supr.*, vol. iv, p. 438.

‡ Optics, book iii, appendix. Query 21.

altogether with a medium which apparently must tend to retard the planetary movements, and which he thought insufficient to account for the ordinary behavior of the luminous ray. He concludes that as "there is no evidence for its existence, therefore it ought to be rejected. And if it be rejected, the hypotheses that light consists in pression, or motion, propagated through such a medium, are rejected with it."* This appears to have been the turning-point in the suspended balance of his judgment, determining his choice between the alternative conceptions of emission and of undulation.

Afterward, as if driven back from every assault to the only retreat, which in earlier years he had stigmatized as "so great an absurdity" that no competent thinker could "ever fall into it," he despairingly asks: "Have not the small particles of bodies certain powers, virtues, or forces, by which *they act at a distance?* . . . . . What I call 'attraction' *may* be performed by impulse, or by some other means unknown to me. I use that word here to signify only in general any force by which bodies tend toward one another, whatsoever be the cause."† And beyond this point, no human research has since been able to penetrate.

This last and presumably deliberate judgment of Newton is a quarter of a century later than the inconsiderate utterances of his third "Bentley letter," which have been so eagerly seized upon by every speculative writer intent on propounding new theories of the universe.

The thoughtful philosopher Doctor Young, about a century later, commenting on Newton's suggestion of an ætherial medium—rarer toward and within dense bodies,—with great ingenuity remarks: "The effects of gravitation might be produced by a medium thus constituted, if its particles were repelled by all material substances with a force decreasing like other repulsive forces, simply as the distances increase. Its density would then be everywhere such as to produce the appearance of an attraction varying like that of gravitation. Such an ætherial medium would therefore have the advantage of simplicity in the original law of its action, since the repulsive force which is known to belong to all matter would be sufficient, when thus modified, to account for the principal phenomena of attraction.

"It may be questioned whether a medium capable of producing the effects of gravitation in this manner would also be equally susceptible of those modifications which we have supposed to be necessary for the transmission of light. In either case it must be supposed to pass through the apparent substance of all material bodies with the most perfect freedom, and there would therefore be no occasion to apprehend any difficulty from a retardation of the celestial motions, the ultimate impenetrable particles of matter being perhaps scattered as thinly through its external form as the stars are scattered in a nebula, which has still the distant appearance of a uniform light and of a continuous

Loco citat. Query 28.

† *Loco citat.* Query 31.

surface; and there seems no reason to doubt the possibility of the propagation of an undulation through the Newtonian medium with the actual velocity of light. It must be remembered that the difference of its pressure is not to be estimated from the actual bulk of the earth or any planet alone, but from the effect of the sphere of repulsion of which that planet is the center; and we may then deduce the force of gravitation from a medium of no very enormous elasticity.

"We shall hereafter find that a similar combination of a simple pressure with a variable repulsion is also observable in the force of *cohesion*; and supposing two particles of matter (floating in such an elastic medium capable of producing gravitation) to approach each other, their mutual attraction would at once be changed from gravitation to cohesion upon the exclusion of the portion of the medium intervening between them. This supposition is however, directly opposite to that which assigns to the elastic medium the power of passing freely through all the interstices of the ultimate atoms of matter, since it could never pass between two atoms cohering in this manner. We cannot therefore at present attempt to assert the identity of the forces of gravitation and cohesion so strongly as this theory would allow us to do if it could be established." *

In his succeeding lecture "On Cohesion," Dr. Young adds at its conclusion: "With respect to the ultimate agent by which the effects of cohesion are produced, if it is allowable to seek for any other agent than a fundamental property of matter, it has already been observed that appearances extremely similar might be derived from the pressure of a universal medium of great elasticity; and we see some effects so nearly resembling them, which are unquestionably produced by the pressure of the atmosphere, that one can scarcely avoid suspecting that there must be some analogy in the causes. Two plates of metal which cohere enough to support each other in the open air will often separate in a vacuum. . . . . But all suppositions founded on these analogies must be considered as merely conjectural; and our knowledge of every thing which relates to the intimate constitution of matter, partly from the intricacy of the subject, and partly for want of sufficient experiments, is at present in a state of great uncertainty and imperfection." †

Very curiously, this ingenious scheme of *universal* repulsion leaves no room for that self-repulsion of matter exhibited in the phenomena of elasticity. That Young did not regard these speculations as reposing on a very firm basis is shown by his memoir "On the Theory of Light and Colors," in which the fourth "hypothesis" assumes the æther to be *denser* within transparent bodies, and for a small distance around them, than in the spaces beyond such bodies. ‡

*Lectures on Natural Philosophy. 1807, 2 vols. quarto. Lect. xlix, vol. i, pp. 616, 617.

† *Loco citat.* Lecture 50, p. 630.

‡ Philosophical Transactions of the Royal Society, 1802, vol. xcii, p. 21, and Young's Lectures on Natural Philosophy, vol. ii, p. 618.

Conditions of the Problem.

It is well to bear in mind that every hypothesis directed to the explication of gravity, is required *in limine* to give a satisfactory account of the following six characteristics of this mysterious influence:

1st. Its *direction* is radial toward the acting mass, or rectilinear—indefinitely. This rectilinear traction is incapable of deflection by any intermediate force. It suffers neither disturbance nor interference from any multiplication of similar lines of action, and admits neither of reflection, refraction, nor of composition.

2d. Its *quantity* is exactly proportional to the acting mass—indefinitely. Corollary: hence,

2d *b*. Its *integrity* of action is complete with every accumulation of additional demand—indefinitely; that is to say, no multiplication of duty in the slightest degree impairs its previous tensions.

3d. Its *intensity* is diminished by recession, in proportion to the square of the distance through which it acts—indefinitely; in a manner somewhat analogous to—but (as modified by the second condition) radically different from—the action of light.

4th. Its *time of action* is instantaneous throughout all ascertained distances, and therefore presumably—indefinitely. Corollary: hence,

4th *b*. Its *rate of action* (if the expression may be tolerated) is precisely the same on bodies at all velocities—indefinitely. It no more lags on a comet approaching the sun at the inconceivable speed of two hundred miles in one second than on a body at the lowest rate of motion, or than on the same comet receding from the sun at the same velocity.

5th. Its *quality* is invariable under all circumstances—indefinitely. It is entirely unaffected by the interposition of any material screen, whatever its character or extent; or in other words, it can neither be checked by any insulator nor retarded by any obstruction.

6th. Its *energy* is unchangeable in time, certainly for the past two thousand years; presumably—indefinitely. Corollary: hence,

6th *b*. Its *activity* is incessant and inexhaustible—indefinitely; the ceaseless fall of planets from their tangential impulses involving no dynamic expenditure in the sun or in other known matter.

It is scarcely necessary to add, as the necessary outcome of the latter propositions, that gravitation is a property immutable and inconvertible. As in the 1st proposition, *two* terminal elements (m' and m'') are necessarily assumed for determining the direction and measure of the radial straight line of action; and as in the 2d proposition, "the acting mass" (m) is the product of these two elements, ($m'.m''$,)—the action being reciprocal; so in the 3d proposition, the measure of the diminution of intensity (d^2) has reference to the same two elements, between whose dynamic centers the value of the distance d is taken. And the expression for these propositions considered collectively is $\frac{m'.m''}{d^2}$ as the measure of the combined quantity and intensity of the traction between the two given elements. If we regard m'' as incomparably smaller than m', (as for example, a one-pound spherical iron shot thrown to a distance from our terrestrial globe,) its mass may be entirely neglected as a vanishing quantity, and we have the simpler expression $\frac{m'}{d^2}$ as indicating the amount of action exercised by our earth upon such a ball.

No hypothesis failing to embrace each of these six requirements deserves consideration; and any hypothesis fully covering them all, might be expected to account equally for the quite incomparable actions of elasticity, magnetism, affinity, and cohesion, before being entitled to acceptance as a just or comprehensive theory of molecular force.

As the projectors of *kinetic* systems of gravitation have almost invariably quite ignored the fourth of the above conditions, it is worth while here to dwell somewhat upon this point. Swift as the earth's orbital motion is, (upward of 18 miles in one second,) the velocity of light is about ten thousand times greater, being 185,000 miles per second. And yet the composition of these two velocities gives a displacement or "aberration" of the heavenly bodies, as seen from our earth, of about 20″ of angle for the observed direction of the visual ray. A luminous impulse emanating from the sun requires about 8¼ minutes to reach the earth. Were the gravitative influence supposed to be so much swifter than light as to require but a single minute to pass through this distance, there would still be a corresponding gravity "aberration" of 2.4″ of angle. The effect of this slight obliquity of traction would be an acceleration of the earth's orbital velocity which would become measurable in a single year.

This is a subject which has been very fully and carefully investigated by astronomers; and the illustrious Laplace, when he found an unexplained minute acceleration in the moon's orbit, threw out the suggestion that if the velocity of transmission of gravitation did not exceed eight million times that of light, it would satisfactorily explain the lunar anomaly. It is scarcely necessary to say that when he subsequently discovered the secular diminution of eccentricity in the earth's orbit, at present continuing, (though slowly reaching its minimum,*) he recognized the true cause of the moon's irregularity, which no longer permitted even the unimaginable limit of possible velocity he had provisionally assigned for gravitative action.

Arago has remarked: "Now if we apply to the perturbation the maximum value which the observations allow, when they have been corrected for the known acceleration due to the variation of the eccentricity of the terrestrial orbit, we find the velocity of the attractive force to amount to *fifty millions* of times the velocity of light."†

* The minimum eccentricity will be reached in about one "precession" period, or 25,000 years hence.

† Popular Astronomy, book xxiii, chap. 27, vol. ii, p. 469 of the English edition. To represent the real meaning of this velocity, it may be put into the equivalent form, that if gravity occupied the one hundred-thousandth of a second in passing from the sun to the earth, it would be detected. Or, the time required to reach us from the nearest star (distant in light-travel about three years) would not exceed two seconds.

If it is possible to represent in such terms the lowest assignable limit of transition, it is because we are furnished with a test of planetary movement of most marvelous delicacy in the record of eclipses occurring at a particular locality 2,000 years ago;—fixing the relation of annual revolution to diurnal rotation with an almost absolute precision. Sir John Herschel remarks: "From such comparisons Laplace has concluded that the sidereal day has not changed by so much as *one-hundredth of a second* since the time of Hipparchus!"* This implies the absence of even an infinitesimal "aberration" of the gravity radiant, or the negation of any assignable interval for its full and complete action. Hence the fourth category above stated.

The same consideration serves to show that the *energy* of gravity has undergone no abatement or change during the lapse of two thousand years. Hence the sixth category.

It is but just however, to notice here that a minute outstanding anomaly of the moon, detected in recent years, and still unexplained, detracts somewhat from the accuracy of the above infinitesimal measure; though it does not impair the value of the general argument. Every investigation, every calculation, of the astronomer, assumes the action of gravity to be for all distances,—absolutely instantaneous.

VILLEMOT. 1707.

Philippe Villemot, a French doctor of theology, and a distinguished mathematician, published at Lyons in 1707 an astronomical treatise, entitled *Nouveau Système, ou Nouvelle Explication du Mouvement des Planètes*, in which, referring the movements of the planets to Cartesian vortices, he announced the theory that their gravitation is occasioned by a difference of pressure, on their outer and inner faces, of the fluid constituting the solar vortex, owing to an increase of its density outward from the sun. The general conception is obviously somewhat similar to the speculation cursorily hazarded by Newton in 1679, and again recurred to by him (though only transiently) in 1717, or ten years later than the above publication by Villemot.

The details of this system cannot here be given, from want of access to his work. The *Nouveau Système*, however, appears to have been very favorably received by the author's contemporaries.

BERNOUILLI. 1734.

It is now nearly a century and a half since the elder John Bernouilli, of Switzerland, the illustrious mathematician, (professor at the universities of Gröningen and afterward of Basel,) imagined a method of accounting for the action of gravitation by centripetal impacts from without. Still retaining his early prepossessions in favor of the philosophy of Descartes, he devised a very curious combination of ætherial vortices and Newtonian emissions. This eclectic hypothesis was promulgated

* Outlines of Astronomy, chap. xviii, sec. 908.

in a competitive memoir on the cause of "The Mutual Inclination of the Planetary Orbits," which obtained the prize of the French Academy of Sciences in 1734. This treatise is divided into four parts, the first three of which are occupied with his exposition of the cause of gravitation, and the fourth with the main question proposed.*

Referring to the respective systems of Descartes and Newton, Bernouilli finds in each "insurmountable difficulties," hence "a just mean between the two appears the safer course. . . . The gravitation of the planets toward the center of the sun, and the weight of bodies toward the center of the earth, are not caused either by the attraction of Newton, or by the rotary force of the vortex medium of Descartes, but by the immediate impulsion of a substance which under the form of what I call a 'central torrent,' is continually thrown from the whole circumference of the vortex to its center, and consequently impresses on all bodies encountered by it in its path the same tendency toward the center of the vortex. . . . And all that Newton has derived from his 'attractions' are by my theory, derived from the impulsions of the *central torrent.*" †

"According to my system, two kinds of matter are conceived as occupying planetary space, and also two principal movements in the celestial vortex. One of these materials I conceive as perfectly fluid, or I would say, actually divisible without limit; that is, it is not composed of elementary corpuscles, as ordinary fluids are conceived, which according the number and size of their constituent particles, present more or less sensible resistance to bodies moving in them, but being perfectly uniform and without structure, is also without resistance." This matter is called the *primal element*; which was employed by the Creator in forming the corpuscles of sensible matter, definite small portions being compacted together into the coherent molecules of matter of the *second element.*

"Matter of the primal element, being perfectly fluid without coherence, presents no resistance to bodies moving within it; for the resistance of fluids comes only from the inertia of the molecules of which they are composed."‡ This primal element, being without constituent parts and without inertia, is as the author states, the same in effect as a perfect vacuum.

"The celestial vortex is composed in great part of the primal element, in which is mingled however, a considerable portion of the second element." According to Bernouilli's view, "the rotation of this vortex is not so rapid as to carry the planets around the sun, as Descartes assumed." In fact, its rotary velocity is in a subsequent portion of the memoir stated to be so low as to amount to only about one two hundred and thirtieth of the orbital velocity of the planets, an approximation to the

* Published in the *Piéces de Prix de l'Académie de Paris,* tom. v, and included in his collected works under the title *Essai d'une Nouvelle Physique Céleste.*

† Johannis Bernoullii, *Opera Omnia,* 4 vols. 4to. Lausanne and Geneva, 1742; vol. iii, sec. viii, pp. 270, 271.

‡ *Loco citat.,* sections x and xvi, pp. 273, 276.

Keplerian third law being however maintained. Thus the vortex survived its primary purpose and function. The small centrifugal motion of the matter of the second element contained in the celestial vortex is sufficient to make it denser at the outer than at the inner portion, though leaving it still too rare to sensibly affect the motions of the outer planets.*

The primal element collected and condensed at the center of each vortex forms a star or sun, though neither the cause nor the manner of such condensation is very clearly unfolded. This central mass agitated with intestine motions of extreme violence in all directions, as in a boiling caldron, produces an intense light and heat, while detached particles at the surface, continually more and more broken up by the frequency and impetuosity of their collisions, acquire a subtilty transcending all conception of the imagination, and are finally thrown off in all directions with explosive force to immense distances, and with the velocity known as that of radiant light. These infinitely small particles, forming the luminous "effluvias" incessantly springing from the sun in radial lines, pass without obstruction through the pores or interstices of the grosser matter forming the planets, though losing at their surface their luminiferous property.

Beyond the orbit of Saturn they encounter more and more of a similar material collected at the outer confines of the vortex; and, while a large number pass into adjacent vortices and continue their course unimpeded, a large number suffer collision by direct impacts from the similar radiations from these vortices. Being inelastic they are mutually arrested, and form molecules of various size, according to the number of such collisions suffered, until impelled by the resultant of these impacts, they either pass into adjoining vortices or back into their own in the form of material molecules of the second element, with correspondingly reduced velocities.†

"In this manner we conceive there must continually descend from the heavens a copious and impetuous rain of pellets, driven inward by the shocks of molecules from surrounding vortices." This converging or centripetal shower of pellets, called the "central torrent," perpetually deluging the sun, forms the compensation and nourishment for its ceaseless waste, as the evaporated water condensing into rain-drops replenishes the constant waste of the sea. These minute balls, having only the amount and direction of motion imparted to them at the boundaries of the vortex, are yet supposed to fall with mathematical precision toward the center of the sun without ever touching each other as they approach. Notwithstanding the efforts expended by the author in attempting to establish this necessity, this centripetal directness undoubtedly remains physically the weak point of his hypothesis.

As the inter-vortical molecules acquire different magnitudes before

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* *Loco citat.*, sections xviii, xix, pp. 278, 279.

† *Loco citat.*, sec. xxviii–xxxvi.

being finally driven toward the center of any system, they will also have differing rates of *descent*, "their velocities being inversely as their masses, so that if one should become a thousand times larger and slower than the impelling particle of light, it would still have a velocity equal to the diameter of the earth in one minute;" and the average speed would be much greater than this, though always much less than the velocity of light. "The central torrent with such a velocity would expend its force on any body which it encountered; and this is precisely the gravitation of the planets toward the sun." And as the various sizes of the minute balls would permit them to penetrate the pores of gross matter to varying depths before being arrested, their impulses would be distributed through the mass instead of being entirely expended on the surface.*

The particles of light radiated by very distant stars, having to run the gauntlet of all the intermediate stellar vortices, might be supposed to be very much obstructed and reduced in number, if not in some cases entirely suppressed.

Each planet and satellite has its subordinate vortex, in which the same play of impalpable effluvia and returning torrent is carried on; and although this is treated as a very obvious corollary of the system, it is one somewhat difficult to fully formulate or realize. Whether two independent masses of lead or iron also attract each other impulsively by virtue of their own special vortices, with atomized radiations and resulting central torrents, is not so definitely made out.

Such then is the *primum mobile* of the planetary gravitations; and with an admirable complacency, Bernouilli contrasts the system of Newton with his own, in which the elementary particles of matter, having no pores, receive the gravitative impulse necessarily on their surfaces. "Now if it were the essential nature of bodies to 'attract' each other, it is evident that elementary particles would gravitate in proportion to their *solidity*, and not in the ratio of their surface, and that . . . . consequently their attraction should diminish in the ratio of the cubes of the distance, instead of as the squares. . . . What then becomes of the system of M. Newton, when its very foundation is tumbled into ruins? I am surprised that not one of the partisans of this hypothesis has perceived this incongruity, in attributing attraction as an essential quality, not only to large masses, but even to the elementary particles destitute of pores!" †

It is scarcely necessary to criticise this wonderful system of "Celestial Physics." The *condensation* of the impalpable atoms of caloric, without adhesions and without attractions, (and seemingly without inertia,) into the dynamic gravific molecules of the "central torrent," is a phenomenon certainly as recondite as the gravitation these molecules are summoned to impel. It is sufficient to say that the *Nouvelle Physique* satisfies no single condition of the six formerly indicated as essential pre-requisites.

* *Loco citat.*, sec. xxxvii–xl. † *Loco citat.*, sec. xlii, p. 299.

It may be added, that in the fourth book of this labored treatise, the inclination of the ecliptic plane to that of the solar equator and vortex, is supposed to be due to a deviation or drift resulting from the oblong or *prolate* form of the revolving spheroidal earth."*

That such an essay should have been crowned by the Academy (the prize however being shared between John Bernouilli and his son Daniel as an independent competitor) appears in our day, notwithstanding the mathematical pre-eminence of its author, a somewhat unfavorable illustration of the scientific character of the age. Bernouilli has however left us the statement of an elementary truth, which may appropriately close this notice: "In physics we should banish the practice of explaining phenomena by chimerical principles more obscure than those presented for investigation."†

LESAGE. 1750.

Some fifteen years later, another bold scheme of universal impact or pressure, designed to explain and supersede "attraction," was conceived by Georges-Louis Lesage, a French-Swiss physicist and mathematician. By means of an infinite number of "ultramundane corpuscles" of transcendent minuteness and velocity, traversing space in straight lines in all directions, atoms and masses of matter are impelled together differentially in the lines of their reciprocal mechanical shadows, or in the direction in which the rectilinear impulses of the "corpuscles" are uncounteracted by opposing ones, from the intervention of other atoms or masses.

To quote Arago's exposition of the theory, "A single body placed in the midst of such an ocean of moving corpuscles would remain at rest, since it would be equally impelled in every direction. On the other hand, *two* bodies ought to advance toward each other, since they would form a mutual screen, as their opposed surfaces would no longer be hit in the direction of the line joining them by the ultramundane corpuscles, and there would then exist currents, the effect of which would no longer be neutralized by opposite currents. Moreover, it will be readily seen that two bodies plunged into such 'gravitation fluid' would tend to approach each other with a force varying inversely as the square of the distance."‡

Although this scheme presents merely the exchange of one incomprehensible agent for another, it is perhaps one of the most ingenious attempts ever made to substitute the conception of primæval *motion* for that of static *tension*.

Lesage was only twenty-three years old, when in 1747 he first devised

* The measurements of a meridional arc of the earth by James Casini, not long previously, had brought out the curious result that the polar axis of the earth is its longest diameter.—*Traité de la Grandeur et de la Figure de la Terre.* Paris, 1720.

† *Opera: loco citat.*, sec. xxxii, p. 288.

‡ Popular Astronomy, book xxiii, chap. 27, vol. ii, p. 468.

his system of nature; and it is related in his biography that in the enthusiasm of his supposed discovery of so august a secret, he cried out, in the words of the Syracusian Sage, "*eureka! eureka!*" and though late at night, he immediately wrote to his father, under date of January 15, 1747, "*Ευρηκα! ευρηκα!* Never have I felt such satisfaction as at this moment, in which I have just succeeded in explaining completely, by the simple laws of rectilinear movement, the principle of *universal gravitation!*"

His first production (written in unsuccessful competition for a prize of the Academy) was an *Essai sur l'origine des forces mortes*, in 1749. This memoir was principally occupied with his mechanical basis of gravitation. Lesage wrote much, and published little. A memoir by him entitled *Essai de Chimie Mécanique*, which explained the phenomena of elective affinities by currents of ultramundane corpuscles of unequal size, was crowned by the Academy of Rouen in 1758. Another essay by him entitled *Loi qui comprend toutes les Attractions et Répulsions*, was published in the *Journal des Savants*, for April, 1764. Eighteen years later, he wrote a dissertation entitled *Lucrèce Neutonien*, more fully developing his system, and comprising a response to the objections which had been urged against it. This treatise was published in the *Mémoires de l'Académie de Berlin*, for 1782. He also left a *Traité des Corpuscles ultramondaines*, alluded to with high praise by Prevost in his account of Lesage's life and works, but which appears never to have been published.

For more than fifty years did Lesage, with unwavering faith, proclaim his doctrine of what he called the "gravific fluid," and urge upon his contemporaries its adoption; but without success. The scheme has been rejected by intelligent physicists and astronomers as valueless in dealing with the complex facts of nature.

Of the six requirements heretofore specified, it will be found to satisfy but two,—the first and the third. So far from fulfilling for example the second condition, (the ratio of mass,) on which Lesage himself most confidently expatiated, it can apparently give no true account of the behavior of a series of atoms placed in a line between two outer ones. The author supposed that he had covered the ground by the assumption that material atoms are so exceeding small in comparison with their interspaces that but few of the flying "corpuscles" will encounter the atoms. Professor Tait, of the University of Edinburgh, has remarked: "It is necessary also to suppose that particles and masses of matter have a cage-like form, so that enormously more corpuscles pass through them than impinge upon them; else the gravitation action between two bodies would not be as the product of their masses."* While this supposition fails notably to give a satisfactory mathematical representation of the observed facts, (on any assignable ratio of impact to percolation,) it is of course quite inadmissible with respect to atoms themselves. In-

* Lectures on Recent Advances in Physical Science, London, 1876, Lect. xii, p. 300.

deed, if the atoms of matter are porous or penetrable to the "ultramundane corpuscles," the third condition will remain unsatisfied.

This corpuscular system of course entirely ignores the fourth condition of the problem, and its fundamental postulate stands in direct opposition to the fifth condition. It is certainly impossible, on any quantitative assumption or numerical estimate whatever, to represent by this scheme the earth's residual gravitation toward the sun during an eclipse of the moon.

Professor J. Clerk Maxwell, discussing the theory of Lesage, observes that if the number of ultramundane corpuscles arrested by our earth is by supposition much less than the number arrested by the sun, "the proportion of those which are stopped by a small body, say a one-pound shot, must be smaller still in an enormous degree, because its thickness is exceedingly small compared with that of the earth. Now the weight of the ball, or its tendency toward the earth, is produced according to this theory, by the excess of the impacts of the corpuscles which come from above, over the impacts of those which come from below and have passed through the earth. Either of these quantities is an exceedingly small fraction of the momentum of the whole number of corpuscles which pass through the ball in a second, and their difference is a small fraction of either, and yet it is equivalent to the weight of a pound. . . . . Now the energy of a moving system is half the product of its momentum into its velocity. Hence the energy of the corpuscles which by their impacts on the ball during one second, urge it toward the earth, must be a number of foot-pounds equal to the number of feet over which a corpuscle travels in a second, that is to say, not less than thousands of millions. But this is only a small fraction of the energy of all the impacts which the atoms of the ball receive from the innumerable streams of corpuscles which fall upon it in all directions. Hence the rate at which the energy of the corpuscles is spent in order to maintain the gravitating property of a single pound is at least millions of millions of foot-pounds per second. What becomes of this enormous quantity of energy? . . . . The explanation of gravitation falls to the ground if the corpuscles are like perfectly elastic spheres, and rebound with a velocity of separation equal to that of approach. If on the other hand they rebound with a smaller velocity, the effect of attraction between the bodies will no doubt be produced; but then we have to find what becomes of the energy which the molecules have brought with them but have not carried away. If any appreciable fraction of this energy is communicated to the body in the form of heat, the amount of heat so generated would in a few seconds raise it, and in like manner the whole material universe, to a white heat."*

Hence the energy expended by the ultramundane corpuscles in giving motion to material masses must be so much abstracted from their aggregate store of velocity; and from the constantly-increasing num-

*Encyclopædia Britannica, ninth edition, 1875, article "Atom," vol. iii, pp. 46, 47.

ber of such corpuscles which must thus be more or less "spent" in fulfilling their appointed function, it follows that the total activity of bombardment on matter cannot be as vigorous now as it was a million years ago, and must be still less vigorous a million years hence; all which is contrary to the unchangeable continuity of gravity affirmed by our sixth condition.

As has been well remarked by an able anonymous writer in the North British Review, "The attraction of gravitation is not as the surface of the bodies, but as their mass. Lesage had therefore to suppose his solid bodies not solid, but excessively porous, built up of molecules like cages, so that an infinite number of atoms went through and through them, allowing the last layer of the sun or earth to be struck by just as many atoms as the first, otherwise clearly the back part of the sun and earth would gravitate more strongly than the front or nearer sides, which would be struck only by the siftings of the previous layers of matter. This notion involves a prodigious quantity of material in the shape of flying atoms, where we perceive no gross matter, but very little material in solid bodies, where we do find gross matter; and it further requires that the accumulation of atoms which strike the solid bodies perpetually should be insensible."*

Not only does the "gravific fluid" utterly fail to give an approximate representation of the actual conditions of the planetary movements, but as must be evident, it will not permit the continued existence of any such movements. A mass moving in free space in any direction excepting directly toward a similar mass, must receive a more active shower of corpuscles in its front than in its rear, and must thus be retarded by a differential of energy directly proportioned to its velocity. Every planet must accordingly encounter a tangential resistance to its orbital motion, proportional to its own gravitation and to its velocity.

As illustrative of the different estimates of this hypothesis formed by distinguished men, the following citations may be permitted. M. Pierre Prevost, professor of philosophy and general physics in the University of Geneva, published two years after the death of Lesage, an account of his writings, in which, after a sketch of his corpuscular hypothesis, he remarks, "I pause at the foot of this majestic edifice with a sentiment of hope; persuaded that the labors of the founder will not be suffered to perish, and that men of genius will share with me the admiration it has inspired."† And Professor Tait regards it as "the only plausible answer to this [great problem] which has yet been propounded."‡ Sir John Herschel, on the other hand, has remarked, "The hypothesis of Lesage which assumes that every point of space is penetrated at every instant of time by material particles *sui generis*, moving in right lines in every possible direction, and impinging upon the ma-

* North British Review, March, 1868, vol. xlviii, p. 126 of American edition.

† *Notice de la Vie et des Écrits de G.-L. Le Sage*, published at Geneva in 1805.

‡ Lectures on Physical Science, *loco citat.*, p. 299.

terial atoms of bodies, as a mode of accounting for gravitation, is too grotesque to need serious consideration; and besides will render no account of the phenomenon of elasticity."*

As an interesting illustration of Lesage's range of intellectual activity, it may be mentioned that to him belongs the credit of having devised, constructed, and operated, in his native city, Geneva, in 1774, the first working electric telegraph.† His system consisted in the employment of an insulated wire for each letter, terminating in an electroscope at the receiving-station. He also wrote a *Dissertation sur l'électricité applique à la Transmission des Nouvelles*:—the first treatise on the electric telegraph.

EULER. 1760.

Leonard Euler, the eminent Swiss mathematician and philosopher, (a pupil of Bernouilli previously referred to,) entertained an indefinite impression that the ætherial medium is in some way a connecting link between the celestial bodies, inducing that mutual tendency to approach commonly called "attraction." Only some dozen years later than the date of Lesage's first conception, he briefly discussed the subject in his celebrated "Letters" commencing in 1760.

He thus comments on the action of gravity: "Supposing a hole made in the earth through its center; it is clear that a body at the very center must entirely lose its gravity, as it could no longer move in any direction whatever, all those of gravity tending continually toward the center of the earth. Since then a body has no longer gravity at the center of the earth, it will follow that in descending to this center, its gravity will be gradually diminished; and we accordingly conclude that a body penetrating into the bowels of the earth loses its gravity in proportion as it approaches the center. It is evident then that neither the intensity nor the direction of gravity is a consequence from the nature of any body, as not only its intensity is variable, but likewise its direction, which, on passing to the antipodes, becomes quite contrary."‡

After some further exposition of the effects of gravitation, as observed in the courses of the planets, Euler indulges in some speculation on the probable nature of this influence. "But in attempting to dive into the mysteries of nature, it is of importance to know if the heavenly bodies act upon each other by impulsion or by attraction; if a certain subtile invisible matter impels them toward each other; or if they are

* Fortnightly Review, July 1, 1865, vol. i, p. 438.

† "The earliest attempt to apply frictional electricity to telegraphy seems to have been made by Lesage, of Geneva, who, in 1774, constructed a telegraph consisting of twenty-four insulated wires." (George B. Prescott, Electricity and the Electric Telegraph, 8vo, N. Y., 1877, chap. xxix, p. 414.)

‡ *Letters a une Princesse d'Allemagne*, Let. 50, 30th August, 1760. This work, since so popular, was republished in England, "Letters on different subjects in Physics and Philosophy, addressed to a German Princess." Translated from the French by Henry Hunter, 2 vols. 8vo, London, 1802.

endowed with a secret or occult quality, by which they are mutually attracted. On this question philosophers are divided. Some are of opinion that this phenomenon is analogous to an impulsion; others maintain with Newton, and the English in general, that it consists in attraction."*

"To avoid all confusion which might result from this mode of expression, it ought rather to be said that bodies move as if they mutually attracted each other. This would not decide whether the powers which act on bodies reside in the bodies themselves or out of them; and this manner of speaking might thus suit both parties. Let us confine ourselves to the bodies which we meet with on the surface of the earth. Every one readily admits that all these would fall downward, unless they were supported. Now the question turns on the real cause of this fall. Some say that it is the earth which attracts these bodies, by an inherent power natural to it; others that it is the æther, or some other subtile or invisible matter, which impels the body downward, so that the effect is nevertheless the same in both cases.

"This last opinion is most satisfactory to those who are fond of clear principles in philosophy, as they do not see how two bodies at a distance can act upon each other if there be nothing between them. . . . . Let us suppose that before the creation of the world, God had created only two bodies, at a distance from each other; that absolutely nothing existed outside of them, and that they were in a state of rest; would it be possible for the one to approach the other, or for them to have a propensity to approach? How could the one feel the other at a distance? Whence could arise the desire of approaching? These are perplexing questions. But if you suppose that the intermediate space is filled with a subtile matter, we can comprehend at once that this matter may act upon the bodies by impelling them. The effect would be the same as if they possessed a power of mutual attraction. Now as we know that the whole space which separates the heavenly bodies *is* filled with a subtile matter called æther, it seems more reasonable to ascribe the mutual attraction of bodies to an action which the æther exercises upon them, though its manner of acting may be unknown to us, than to have recourse to an unintelligible property. . . . . . As the idea of all occult qualities is now banished from philosophy, attraction ought not to be considered in this sense."†

It does not appear how so vague and inexplicable a supposition is calculated to commend itself "to those who are fond of clear principles in philosophy." In his anxiety to avoid an "occult quality" in matter, this learned writer seems quite unconscious of the fact that by investing his æther with an "unknown manner of acting," he is just as fatally "having recourse to an unintelligible property." Certainly, just as "perplex-

*Letters, &c. Let. 54, 7th September, 1760.

† Letters, &c. Let. 68, 18th October, 1760.

ing questions" are suggested by the hypothesis of æther pressure, as by the hypothesis of an original "propensity to approach."

The speculation however, is too indeterminate to admit of precise criticism; and is noteworthy only from the eminence of its proposer. It is a little remarkable that Euler, although in correspondence with Lesage, makes no allusion to his hypothesis.

HERAPATH. 1816.

Passing over a few names of less note in this connection, (Berthier, Churcol, and others,) we find a somewhat more developed attempt at unveiling the standing enigma, presented in the writings of John Herapath, of Bristol, England. In a preliminary essay, published in Thomson's *Annals of Philosophy*, "On the Physical Properties of Gases," he announced the hypothesis of "one cause for heat, light, gravitation, electricity, cohesion, ærial repulsion, &c., from which all these flow, and are easily deducible; and their effects may be computed by mathematical induction. [deduction ?] It shows us that gravitation, cohesion, and affinity, are but the same thing under different modifications; that the differences of the two latter arise from a difference in the figures and sizes only of the particles; that attraction and repulsion are not properties of matter."* This hypothesis thus briefly stated by its author, at the age of twenty-three years, does not appear to have been further publicly elaborated for five years.

In 1821, Herapath contributed to the same journal a memoir entitled "A Mathematical Inquiry into the Causes, Laws, and principal Phenomena of Heat, Gases, Gravitation, &c.," memorable as presenting by far the fullest and clearest exposition of the mechanical theory of heat and of gases that had at that time been propounded. He states that about ten years earlier, while engaged in investigating an anomaly found in his calculations of lunar equation, his attention had been accidentally directed to Newton's suggestions as to the cause of gravitation; and he proceeds:

"If gravitation depends upon the action of an elastic medium such as Newton supposed, which grows rarer and rarer as you approach the dense bodies of the sun and planets, there ought to be some reason for this variation of density; and as Newton has not, as far as I could perceive, given any, I began to consider what it might be. And after some little thinking, it occurred to me that if this medium be of the same nature as our atmosphere and other gaseous bodies, that is, if it be capable of being expanded by heat and contracted by cold, then the sun being a very hot body, and the heat being so much the greater the nearer we are to him, the density of the medium ought therefore to decrease with a decreasing and increase with an increasing distance, the same as Newton would have it. And because we find by experience that dense solid bodies receive heat more strongly than much rarer

* Annals of Philosophy, July, 1816, vol. viii, pp. 58, 59.

ones, particularly than gases, the dense bodies of the planets being heated by the solar rays as well as by the medium about them, ought it appeared to me, to be hotter than this medium, and consequently ought to produce the same effects on the medium as the sun, though not in so great a degree. Therefore if as Newton imagines, the particles of the planets be impelled toward the sun by the inequality of the pressure on their further and nearer sides, the denser parts of the medium pressing more forcibly than the rarer, the same reason will likewise hold good why bodies should be impelled toward the planets and other material parts of the system." *

After speaking of the discouragement resulting from his unsuccessful attempts at arriving at the mathematical laws of heat, he proceeds: "Yet sometimes when my thoughts were involuntarily turned this way, the idea that two inanimate bodies could act on each other at a distance without some other means than that of a mere tendency or inclination in them to approach, would appear so strongly unphilosophical, and the apparent coincidence of several phenomena with conclusions I had drawn from my notions of gravitation so very seductive, that I could not avoid thinking the views I had taken were tolerably correct; and that there was only wanting the direction of some happy idea, which patient perseverence might possibly attain, to set the whole in a clear and irrefragable light. Thus between hope and despair, between unceasing attempts and mortifying failures, I continued until May, 1814, at which time my ideas of heat underwent a complete revolution. Previous to this time I had conceived heat to be the effect of an elastic fluid, and on this supposition, had repeatedly attempted to reduce its laws to mathematical calculation; but uniform disappointment at length induced me to give this hypothesis a careful investigation, by comparing it with general and particular phenomena. The result of this investigation convinced me that heat could not be the consequence of an elastic fluid. . . . After I had revolved the subject a few times in my mind, it struck me that if gases instead of having their particles endued with repulsive forces, subject to so curious a limitation as Newton proposed, were made up of particles or atoms mutually impinging on one another and the sides of the vessel containing them, such a constitution of æriform bodies would not only be more simple than repulsive powers, but as far as I could perceive, would be consistent with phenomena in other respects, and would admit of an easy application of the theory of heat by intestine motion. Such bodies I easily saw possessed several of the properties of gases; for instance, they would expand, and if the particles be vastly small, contract almost indefinitely; their elastic force would increase by an increase of motion or temperature, and diminish by a diminution; they would conceive heat rapidly, and conduct it slowly; would generate heat by sudden compression,

* Annals of Philosophy, 1821, vol. xvii, or of new series, vol. i, p. 276.

and destroy it by sudden rarefaction; and any two, having ever so small a communication, would quickly and equally intermix."*

Fanciful as are the considerations which led Herapath to this conclusion, it may be doubted whether a better statement of the dynamic theory of heat, and the modern view of gaseous temperature, has been published in the last half century. Certainly none can be found preceding it. The scientific world was not then however prepared by a sufficient induction to fully appreciate this theory.

These views of thermogenetic gravitation were amplified by their author at a later period, and included in an elaborate and excellent treatise on the general principles of physics, published in 1847, in which work they form the concluding portion, or book iv, comprising four sections.†

Herapath saw very clearly that a theory of molecular collision cannot dispense with resilient impacts; but he announced the startling paradox that atoms "perfectly hard" would on striking each other, rebound just as though they were elastic. This very difficult thesis is discussed at some length (though certainly not convincingly) in his general work,‡ in a chapter on "the collision of hard bodies." The conception of a repellant propensity in the atoms is of course, excluded by the very spirit of the hypothesis. "Only two properties to matter are assumed, namely, inertia and absolute hardness. . . . Our theory deprives the particles of repulsion, or of any active properties, and merely assumes that airs are composed of small particles moving about in all possible directions, and keeping up their state as airs by their mutual collisions and *reflections* from one another and the sides of the containing vessels. From this simple property, and that of heat consisting in corpuscular motion, the whole known laws of gases are deduced with mathematical rigor."§ Unfortunately "two properties" are wholly insufficient either to set or to keep a system of molecules in motion. Matter thus constituted, (with only "two properties,") with any amount of motion superimposed, could never make a cosmos. The "stubborn fact" of *elasticity* has indeed been the insuperable obstacle and embarrassment of all kinetic schemes of molecular physics.

"By extending the principles to find the temperatures of the planets, we arrive at an interesting conclusion, namely: supposing them to be all of the density of our earth, we bring out very nearly the amount of gravitation toward each of them which is actually found to exist. Mercury is not included, as our knowledge about him is uncertain." (Introduction, p. xxv.) Mercury however is excluded, because on the assumption that the absolute temperatures of the planets are inversely as their distances from the sun, the temperature of this inner planet is

* *Loco citat.*, p. 278.

† Mathematical Physics. By John Herapath. 2 vols. 8vo. London, 1847.

‡ Math. Phys., vol. i, pp. 106–137. Huyghens and Wren had both (a century and a half earlier) maintained the same doctrine.

§ Math. Phys., Introduction, pp. xvii, xviii.

found to be too high to satisfy the conditions of the calculation.* If "the amount of gravitation toward each" planet is at all indicated by the relative distance-periods of their satellites, it is very clear that they cannot have the same density.

It might be expected that with the range of temperatures at our command, the influence of heat on attraction could be subjected to the test of direct experiment. It is admitted that "We have no distinct evidence of attraction being either augmented or lessened by heat."†

The radical defect of this ingenious application of the differential of heat-motion as the impelling force of gravity lies in the fallacy that any pressure-differences would, under the circumstances, result from temperature-differences. Our author says: "In Newton's day the notion of a fluid which had no visible tendency to one part of space more than to another, keeping up an equilibrium with itself, and yet able to press heavier on one side of a body within it than on the other, was quite enough to gain incredulity."‡ Nor is it easy to perceive how the notion is made more credible in our day. The rarefaction of a free gas by heat is the direct effect of its increased elastic tension or pressure, and the two are proportional. In other words, if upon the planetary hemisphere exposed to the sun there were fewer impacts of gaseous molecules in a unit of time than on the outer or night hemisphere, these impacts would have a correspondingly higher velocity, so that the whole moment of impulse (or pressure) on the two sides would be precisely equal.

It is doubtful whether this hypothesis (even supposing it operative) could really satisfy any of the six conditions heretofore propounded. With regard to the second postulate, it is evident that the *mass* of the attracting body cannot determine the quantity of attractive action, if heat be the efficient cause. This is very frankly conceded by Herapath, who says of the mass ratio: "This law has been proved experimentally by Sir Isaac Newton; but though this be true, the converse case does not according to our principles hold good, namely that the attractive forces of bodies are directly proportional to their quantities of matter. Our principles do not therefore corroborate Newton's third law of motion, respecting the equality of action and reaction in attracting forces; for by our theory, a body might by the agency of the fluid medium, be impelled toward another, without any reciprocal action; which is by no means surprising if we consider attraction not to be an inherent or essential property of matter, but merely the action of a third body."§ The sufficient answer to all which is, that not only is it unconfirmed by any experimental research, but all experience contradicts the assumption.

* Math. Phys., vol. ii, p. 318.

† Math. Phys., Introduction, p. xv.

‡ *Loco citat.*, Introduction, p. xxxvi.

§ Annals of Philosophy, new series, vol. i, p. 411; and Math. Phys., vol. i, p. 9.

The force of the objection contained in our fourth condition-precedent is thus courageously confronted and defied: "It might be conceived that the attraction would be less on a body moving toward the central body, and greater on one moving from it, which is contrary to what we find by experience. Though regarded mathematically, such an inference would be strictly true, yet since the difference between the forces will depend on the activity of the medium, and since this activity will be increased in proportion to the tenuity of the parts of the medium, it is evident that the ætherial atoms may be so small, and the activity of the medium consequently so great, that the swiftest motions we know of could produce no sensible difference in the vigor of its action." And with a marvelous boldness of assumption he adds: "We may hence fairly conclude that there might be a fluid medium pervading the heavens, and all bodies, of such activity that no sensible difference could be observed in the intensity of its action on bodies in a state of quiescence, or moving with a velocity not only six million, but several million million times greater than that of light!" *

GUYOT. 1832.

Another ingenious attack upon the "Problem," in a somewhat similar though really distinct direction, was made by Dr. Jules Guyot—a French physician,—in a very original and suggestive treatise entitled *Eléments de Physique Générale*, 8vo, published in Paris in 1832, at about the age of twenty-seven years. This writer seems to have had, even at this early date, a general idea of correlating the physical forces.

Assuming with other physicists, two kinds of matter,—one sensible in the gaseous liquid and solid forms, the other insensible, in the "simple elementary and atomic" condition of the ætherial medium, filling all space under a state of constant and enormous pressure, and infinitely more subtile than any particle of combinable matter,—and assuming also two kinds of movement, one of translation and the other of vibration, Guyot maintained that these two forms of motion are reciprocally complementary and convertible, their sum being constant. So that motion is essential to matter, is equally indestructible, and is directly proportional to its mass. He held that light, heat, sound, and the excitations of smell and taste, are all the results of molecular motion or vibration, as are also the agencies of electricity, magnetism, and gravitation.

In a work on the pressures resulting from ærial motions, published in 1835, Guyot records some curious experiments on the influence of vibratory sounding bodies in causing light objects to approach them;—experiments which immediately recall the suggestions made by Dr. Robert Hooke more than a century and a half earlier, and which would certainly have delighted that philosopher. Disks of pith and of paper, delicately suspended near a vibrating tuning-fork, were observed to be

* Annals of Philosophy, new series, vol. i, p. 410.

attracted as it were, to the origin of vibration, with a range of influence approximately proportional to the area of the disk. The same phenomenon was observed with the employment of a bell, when caused to sound by drawing a bow across its edge, excepting that at the *nodes* of oscillation no "attraction" was exhibited.*

In an essay entitled "A synthetic Glance at the Forms and Forces of Matter," published in 1861, the same author, recapitulating his views and observations of 1832 and 1835, and still maintaining that all the properties of bodies are derivatives of their translatory or vibratory movements, and that the equilibrium and the phenomena of the world exist only under the condition of constant *pressure* of the incoercible æther upon coercible matter, and the reaction of the latter upon the former, argues that, "if it be shown that the vibration of the atoms of bodies may and actually does cause a rarefaction in the sphere of activity of each of the atoms," this constitutes a proof that "the approximation of the atoms of bodies of ponderable matter is due to the rarefaction of the imponderable fluid, and consequently to the diminution of its pressure in the space between the atoms of the same body;" and hence that "we are compelled to admit that attraction is a mechanical force, consisting, first, of the rarefaction of the æther between molecules, masses, or the heavenly bodies, resulting from the ceaseless vibration of the atoms of ponderable matter, and secondly, of the reaction from the exterior pressure of the æther upon the same, resulting from the general pressure of the imponderable universal medium which constitutes the *mother-liquor* of the world."†

In this article the writer brings out very distinctly an idea first suggested by Newton, and which has recently been fermenting, so to speak, in the minds of various speculative writers, to wit, that matter as experimentally cognizable by our senses—having for its lowest constituent unit the compounded molecule of uniform structure for each elementary substance, the indivisible "atom" of the chemist—has been by some mysterious process evolved in the indefinite past from the structureless impalpable æther filling immensity. That the ultimate molecule of matter as known to us is a highly complex or organized cosmos, appears to be sufficiently demonstrated by the definite multiple periodicities exhibited by gaseous spectra. If the sympathetic responses

**Des mouvements de l'air et des pressions de l'air en mouvement.* (8vo, Paris, 1835.) Sir Henry C. Englefield, in 1773, observed at Brussels, that during the ringing of a large church bell, (weighing 16,000 pounds,) the ærial vibrations affected a mercurial barometer, which was placed experimentally about seven feet below it, by raising the column about one-hundredth of an inch. (Journal of R. I., vol. i, p. 157.) On which Dr. Young offers the following suggestion : "It is easy to suppose that the law of the bell's vibration was in this experiment such that the air advanced toward the barometer with a greater velocity than it receded, although for a shorter time; and that hence the whole effect was the same as if the mean pressure of the air had been increased." (Lectures on Natural Philosophy, 1807, 2 vols. quarto, vol. ii, p. 270.)

† *Presse Scientifique*, 1861, vol. iii, p. 130.

of the æther indicate a community of nature with the absolute atoms of the molecule, whose tremblings they transmit, we are confronted with the paradox, that while in the molecule these atoms are so firmly bound together that no known forces have ever been able to divorce them, in their isolated or discrete state constituting "the mother-liquor of the world," their repulsions are so intense that no known forces have ever been able to unite them.

It is impossible not to be struck with the originality of speculation and the ingenuity of experimentation by which, as Dr. Guyot believes, he has solved the great problem of energy or dynamic. But it is apparent at a glance that his system is at variance with every feature of the actual phenomenon of gravitation, and fails to represent any of the six conditions-precedent, perhaps excepting the first. If the resultant motion of translation from an acoustic vibration of air (or from a thermal vibration of æther) may be supposed to occur in a right line, it is not established that it can so continue for any considerable distance; and the last five conditions are each and all directly incompatible with the assumption.

Perhaps the most palpable fault of the scheme however, is the violence done by it to the established law of the conservation of energy, while being proclaimed apparently in the interest of that law. A vibrating molecule is supposed to impress its motion upon an investing medium, without parting with any of its original *vis viva;* or in other words, it is miraculously endowed with an inexhaustible fund of dynamic action, and its motion though constantly expended in "work" performed, yet requires no regeneration.

Or on the other hand, if gravitation depend upon the vibrations transmitted from the active molecule as a center to the surrounding æther, this "attractive" action must decline with the expenditure of the vibratory energy, contrary to the observed fact as summed up in the sixth proposition.

FARADAY. 1844.

Although the views announced by Professor Michael Faraday on the subject of gravitation were undoubtedly very vague, he must be classed with the kinetic theorists; and the very influence necessarily attaching to his well-earned reputation as an investigator and experimental physicist, renders a full discussion and a free criticism of his published reflections all the more imperative in the interests of scientific truth.

In "A Speculation on the Nature of Matter," dated January 25, 1844, Faraday remarks: "The safest course appears to be to assume as little as possible; and in that respect, the atoms of Boscovich appear to me to have a great advantage over the usual notion. . . . . A mind just entering on the subject may consider it difficult to think of the powers of matter independent of a separate something to be called *the matter*, but it is certainly far more difficult, and indeed impossible, to think of or imagine that matter, independent of the powers. Now the powers we know and recognize in every phenomenon of the creation; the abstract matter in none; why then assume the existence of that of which we are ignorant, which we cannot conceive, and for which there is no philosophical necessity? . . . . Doubtless the centers of force vary in their distance one from another, but that which is truly the matter of one atom touches the matter of its neighbors. Hence matter will be *continuous* throughout, and in considering a mass of it, we have not to suppose a distinction between its atoms and any intervening space. The powers around the centers give these centers the properties of atoms of matter; and these powers again, when many centers by their conjoint forces are grouped into a mass, give to every part of that mass the properties of matter. . . . . The view now stated of the constitution of matter would seem to involve necessarily the conclusion that matter fills all space, or at least all space to which gravitation extends; for gravitation is a property of matter dependent on a certain force, and it is this force which constitutes matter. In that view, matter is not merely mutually penetrable, but each atom extends, so to say, throughout the whole of the solar system, yet always retaining its own centre of force."*

This result of "assuming as little as possible" thus appears to commence with the Berkeleyan negation of matter, only to conclude that it is omnipresent. When it is inferred however, that every atom separately includes every other atom, it is obviously only *influence* that is conceived of, and not matter at all in any intelligible sense. If we call this multitudinous infinitely-extended and mutually-inclusive influence "matter," there still remains the inexorable necessity of designating by some distinctive title that other form of influence inclosed within the visible tangible surfaces bounding those appearances which are characterized by *inertia*, which are accurately measurable in mass, and which are the objects of all our direct observation and experiment. Neither in formula, nor in idea, therefore,—neither in nominalism, nor in realism,—are we advanced a particle by such speculations.

In a memoir "On the Possible Relation of Gravity to Electricity," read before the Royal Society, November 28, 1850, Faraday remarks: "The long and constant persuasion that all the forces of nature are mutually dependent, having one common origin, or rather being different manifestations of one fundamental power, has made me often think upon the possibility of establishing by experiment, a connection between gravity and electricity, and so introducing the former into the group, the chain of which (including magnetism, chemical force, and heat,) binds so many and such varied exhibitions of force together by common relations." He then records experiments with a tubular helix of covered copper wire of considerable length, and having its extremities connected with long covered wires which were brought to a very sensitive galvanometer, the said coil or helix being allowed to fall about

* L. E. D. Philosophical Magazine, 1844, vol. xxiv, pp. 140-143.

thirty-six feet. No indications however, were perceived in the needle.* Experiments with solid cylinders of copper, iron, glass, &c., secured within the helix were successively made without result. Similar cylinders were then dropped through a *fixed* helix, and also reciprocating motion by mechanical devices was tried, but equally without any effect on the galvanometer needle. Faraday concludes, "Here end my trials for the present. The results are negative. They do not shake my strong feeling of the existence of a relation between gravity and electricity, though they give no proof that such a relation exists."† These experiments were skillfully devised to detect a correlation between the two, if any such existed. Were gravity either a form or a resultant of molecular motion we should certainly expect to find evidence of an expenditure of such motion, proportioned to the energy of the "fall."

Several years later, in a memoir "On the Conservation of Force," Professor Faraday thus states the result of his further meditations on the "attractive" theme of gravitation: "I believe I represent the received idea of the gravitating force aright in saying that it is a simple attractive force exerted between any two or all the particles or masses of matter at every sensible distance, but with a strength varying inversely as the square of the distance. The usual idea of the force implies direct action at a distance; and such a view appears to present little difficulty except to Newton, and a few, including myself, who in that respect may be of like mind with him.‡ This idea of gravity appears to me to ignore entirely the principle of the conservation of force; and by the terms of its definition, if taken in an absolute sense, '*varying* inversely as the square of the distance,' to be in direct opposition to it."§

This singular misconception of his theme, which underlies all his subsequent reasoning, may be briefly rebutted by the simple averment that the *conservation* of force has no relation whatever to the *law* of force, and can have no relation to it. All that the established doctrine affirms, is that be the law what it may, "conservation" demands that none of the resultant effects shall vanish, and that the action of the law shall be absolutely the same in the same conditions. In the case of a dynamic *radiation*—indeed, through a perfectly elastic medium,—con-

* It is evident that whether the earth be contemplated as an electrically-charged globe or as a permanent magnet, the delicate experiments of Faraday, above described, would necessarily give indications thereof in the galvanometer: and it is an interesting illustration of the scientific conscientiousness of the experimenter, to observe with what caution these collateral results were eliminated.

† Philosophical Transactions Roy. Soc., 1851, vol. 141, pp. 1–6. A Mr. Zalewski presented to the French Academy of Sciences, (April 22, and August 19, 1850, and again July 5 and 19, 1852,) memoirs "On Electricity as the Cause of the Effects attributed to Universal Gravitation." (*Comptes Rendus*, 1850, vol. xxx, p. 485; vol. xxxi, p. 255; and for 1852, vol. xxxv, pp. 49 and 95.) "Faraday's insight was so profound, that we cannot assert that something may not yet be discovered by such experiments, but it will assuredly not be conservation of *force*." Professor Tait's Lecture on "Force," Nature, 21st September, 1876, vol. xiv, p. 462.

‡ Referring, of course, to the "third Bentley letter."

§ L. E. D. Phil. Mag., 1857, vol. xiii, p. 228.

servation requires that all the successive spheres described by increasing radii of action shall represent precisely the same amount of energy, which *is* the expression of "inverse squares." But in the case of a primitive force which is *not* radiation, (as in gravity, elasticity, cohesion, or affinity,) the *law* of increment or decrement with distance may have any mathematical value, and may be entirely different and incommensurable with every variety of force.

Unfortunately the human mind has been gifted with no insights or intuitions which can determine the *a priori* certainty of a single fact of natural law. After twenty-five centuries of vainly-struggling speculation, the true law of one kind of force was laboriously ascertained only two little centuries ago. And this result is justly regarded as the most brilliant achievement of the highest human intellect. Did experience teach us that the law of gravity was one of simple decrease of intensity directly with the distance, (in which case the periodic times of the planets would be directly as their distances and their orbital velocities the same at all distances,) or did it teach us that its energy was precisely the same at all distances, as Faraday thinks to be the true desideratum, (in which case the periodic times as well as the orbital velocities would be as the square roots of the distances,) or did it teach us that its intensity *increased* directly as the distance, as by an elastic bond,* (in which case the periods of revolution would be the same for all distances, and the orbital velocities therefore, proportional to the distance,) in each and every case it would still be unalterably true that the energy expended in separating two bodies would be exactly equal to the energy given out in their return to the antecedent position. And *this* is what is meant by the "conservation of force."

Probably no generalization of science has been the occasion of more misapprehension and confusion than this of "conservation." Properly speaking, "Force" is not conserved at all! It is the *offspring* of Force, or "work" that is really conserved. As words necessarily *follow* thought practically no less than genetically, (and sometimes *longo intervallo*,) it results that with the increasing specializations of scientific conception, many words continue to retain their more primitive or "comprehensive type" of meaning, without originating the required varieties or differentiations of expression; and such has been the case with the very useful word "force;" which is employed sometimes in its more generalized sense, as including any stress or action whatever; sometimes as limited to quantity of *motion;* sometimes as synonymous with *energy*, (in which sense alone is "conservation" applicable to it;) sometimes as expressing "the mere *rate* of conversion or transference of energy per unit length of that motion," (with a strong suspicion that "there is probably no such *thing* as force at all;")† and sometimes as signifying

* There is reason to believe that this is actually the law of the atomic orbits.

† Lecture on "Force," by Professor Tait, of Edinburgh. Nature, 21st September, 1876, vol. xiv, pp. 459, 463. It is certain that Newton did not employ the word *Vis* in any such restricted sense, as the learned professor would imply.

primitive innate *tension*, exclusive of all motion, although the parent of all motion. So that while one would limit the word to designate a purely *kinetic* condition of matter, another would limit it on the opposite side to designate a purely *static* quality in matter.

Elasticity is a natural force, having always an entirely different space-potential from gravity, and yet is equally removed in every case from that ratio of uniformity supposed to be the true representation of conservation. In the case of *tensile* elasticity, (as of a rubber band or of a long spiral spring,) the tension increases directly with the distance of elongation.

Professor Faraday thus proceeds to illustrate the difficulty he finds in the ordinary definition of gravity: "Assume two particles of matter, A and B, in free space. . . . Then at the distance of 10 the force may be estimated at 1, whilst at the distance of 1, *i. e.*, one-tenth of the former, the force will be 100; and if we suppose an elastic spring to be introduced between the two as a measure of the attractive force, the power compressing it will be a hundred times as much in the latter case as in the former. But from whence can this enormous increase of the power come?" The answer is, that this increase of "power" comes from either particle being so much nearer the source of the influence. Why this increase should be just one hundred-fold in the case supposed, the present state of science does not furnish any explanation. The result is accepted simply as a very rigorously verified "fact."

"Suppose the two particles A and B removed back to the greater distance of 10, then the force of attraction would be only a hundredth part of that they previously possessed; this, according to the statement that the force varies inversely as the square of the distance, would double the strangeness of the above results; it would be an *annihilation* of force." Here again, the law of intensity, as a function of distance, is confounded with absolute quantity in the agent. Such a confusion could hardly have occurred in discussing the action of a permanent magnet. The actually existing gravity decrement no more involves any "annihilation of force," than would an equality of ratio irrespective of distance involve a *creation* of force, were it found in any case to be true. So far from there being any destruction or loss of force in the crucial case supposed, the doctrine of "conservation" teaches us that the separation of the two particles could be effected only by the expenditure of an adequate amount of energy; and that at their greater distance of 10, these particles would possess a *potential* of position precisely equivalent thereto.

Faraday continues: "According to the definition, the force depends upon both particles; and if the particle A or B were by itself, it could not gravitate, *i. e.* it could have no attraction, no *force* of gravity. . . . As the particles can be separated, we can easily conceive of the particle B being removed to an infinite distance from A, and then the power in A will be infinitely diminished. Such removal of B will be as if it were annihilated in regard to A, and the force in A will be annihilated at the same time."* Although it is certainly true that when B is removed to an infinite distance from A, the power of A *upon B* will be infinitely diminished, it is not a sound inference that "the power *in A* will be infinitely diminished." The same inaccuracy occurs in the assumption that if an isolated particle "could not gravitate" it could have "no *force* of gravity." This is but another expression of the not unusual sophism that force has no existence unless in active exercise.

Varying his illustration to attack the problem of mass, Professor Faraday thus further unfolds his difficulties: "The particle A will attract the particle B at the distance of a mile with a certain degree of force; it will attract the particle C at the same distance of a mile, with a power equal to that by which it attracts B. If myriads of like particles be placed at the given distance of a mile, A will attract each with equal force. . . . How are we to conceive of this force growing up in A to a million-fold or more? And if the surrounding particles be then removed, of its diminution in an equal degree? Or how are we to look upon the power raised up in all these outer particles by the action of A on them, or by their action one on another, without admitting (according to the limited definition of gravitation) the facile generation and annihilation of force?" The substance of this enigma is comprised in the corollary to our second proposition. Striking out the fallacious expression "of this force *growing up* in A," which has already been sufficiently criticised, surely the case as stated, is a very good illustration of "conservation." The hypothetical generation and annihilation of the distant particles surrounding A are just as "facile" as the hypothetical "generation and annihilation of force" exercised by them; but no whit more so. As if one should say, imagine the clock wound up, and it will run a week. The equation is correct only on condition that both the terms are *equally* real or *equally* imaginary.

Inasmuch as the accepted definition of gravitative force (deemed by Faraday so objectionable) is merely the summation of an overwhelming induction derived from a ceaseless observation, the question naturally arises, to what point are the difficulties imagined by him supposed to tend? "The principle of the conservation of force would lead us to assume that when A and B attract each other less because of increasing distance, then some other exertion of power, either within or without them, is proportionately growing up. And again that when their distance is diminished, as from 10 to 1, the power of attraction, now increased a hundred-fold, has been produced out of some other form of power which has been equivalently reduced."† Were gravity merely a dynamic energy, generated in time and space by an anterior and exterior force, the inference would undoubtedly be correct. Conversely, the utter falsity of the inference, as established by all experience, in which

* L. E. D. Phil. Mag. 1857, vol. xiii, pp. 228, 229.

† *Loco citat.*, pp. 230, 231.

experience, as a question of *fact*, the keenest of experimental investigators, Faraday himself, has been able to detect no flaw, the utter falsity of the inference may be taken as conclusive against the premiss. Gravity is thereby proved to be a static *tension*,—incessant, inconvertible, inexhaustible; as affirmed by our fifth and sixth propositions. Whatever *a priori* conceptions may be indulged therefore, as to the natural fitness of a central force having the same tension at all distances, it has been definitely established by two centuries of continuous and irreversible demonstration, that gravity is not such a force. And this announcement is the subject of our third proposition.

"It will not be imagined for a moment," says Faraday, "that I am opposed to what may be called the *law of gravitative action;* that is, the law by which all the known effects of gravity are governed. What I am considering is the definition of the *force* of gravitation. . . . That the *totality* of a force can be employed according to that law I do not believe, either in relation to gravitation, or electricity, or magnetism, or any other supposed form of power."* But the most refined and varied observations (even when conducted by a Faraday) have failed to detect any such supposed residuum of effect, and have substantiated as one of the largest results of our present knowledge the received formula as expressing the "totality" of the force recognized as gravity. Our "beliefs" should always be based upon, and conform to, the observed order of nature. "The safest course appears to be to assume as little as possible."

Faraday thus sums up his own impressions: "For my own part, many considerations urge my mind toward the idea of a cause of gravity which is not resident in the particles of matter merely, but constantly in them and all space." (p. 231.) "I would much rather incline to believe that bodies affecting each other by gravitation act by lines of force of definite amount, or by an æther pervading all parts of space, than admit that the conservation of force could be dispensed with." (238.) Fortunately, the alternative presented possesses no relation of its terms. The unqualified assertion of "conservation" has no bearing whatever on either "lines of force" or the supposed action of "an æther;" and a choice is therefore quite unnecessary.†

On no subject, perhaps, have the distinguished author's ideas been more vague and intangible than on the favorite one of "lines of force." After exhibiting the familiar magnetic curves or chains of iron-filings as a typical phenomenon, he says: "The term *line of force*, as defined above, is restricted to mean no more than the condition of the force in a given place as to *strength* and *direction;* and not to include any idea of the nature of the physical cause of the phenomena. At the same time, if

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* *Loco citat.*, p. 233.

† An excellent review and criticism of Professor Faraday's Memoir on Gravitation, by Professor Brücke, of Vienna, was published in the L. E. D., Phil. Mag., 1858, vol. xv, p. 81.

reason should arise to think that the physical condition of the force partakes generally of the nature of a current or of a ray, a view which the author inclines to, he sees no objection in the term." *

"In the action of gravity, for instance, the line of force is a straight line, as far as we can test it by the resultant phenomena. It cannot be deflected or even affected in its course. Neither is the action in one line at all influenced, either in direction or amount, by a like action in another line."† This is the affirmation made by our first proposition.

Faraday continues: "There is one question in relation to gravity, which, if we could ascertain or touch it, would greatly enlighten us. It is, whether gravitation requires *time.* If it did, it would show undeniably, that a physical agency existed in the course of the line of force. It seems equally impossible to prove or disprove this point, since there is no capability of suspending, changing, or annihilating the power, or annihilating the matter in which the power resides."‡ Some six years before the date of this latter paper, Professor Faraday, in "Thoughts on Ray-vibrations," had suggested more doubtingly, the same inquiry: "I am not aware whether there are any data by which it has been or could be ascertained whether such a power as gravitation acts without occupying time."§

This query finds its answer in our fourth proposition. The writer was evidently not aware that it had been definitely settled by the astronomers, and with a delicacy of precision infinitely beyond the reach of any direct or instrumental research; and not being a mathematician, he very naturally supposed the problem insoluble. Those not trained in the higher operations of the science of "necessary conclusions," have no conception of the resources of mathematical investigation applied to judicious comparisons of accurate observations. And just here the reminder may be permitted, that did the influence of gravitation occupy the millionth part of a second in traversing the distance of a million miles, the astronomer's analysis would easily detect it. This would represent only one-ninth of the velocity estimated by Laplace and Arago, as previously stated.

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* L. E. D., Phil. Mag., 1852, vol. iii, p. 67. Dr. P. M. Roget showed in 1831, by a very neat geometrical demonstration, that these so-called "lines of force" in the magnetic field, are simply the tangential resultants of the *directive* action by the two magnetic poles exerted in straight or radial lines with a ratio of diminished intensity as the square of the distance from either pole, on the minute iron particles regarded as needles. (Journal of the Royal Institution, February, 1831, vol. i, pp. 311–318; and also a treatise on "Magnetism" by the same author, in vol. ii of the "Library of Useful Knowledge," chap. ii, sect. 3, pp. 19–21.) M. Ch. Cellerier has also, by an analytical discussion of the "magnetic curves," established the same conclusion mathematically. (A Treatise on Electricity, by Aug. De La Rive, London, 2 vols., 8vo, 1853. part iii, chap. i. Note D, vol. i, pp. 542–544.)

† Phil. Mag., 1852, vol. iii, p. 403.

‡ *Ibidem*, p. 403.

§ Phil. Mag., May, 1846, vol. xxviii, p. 349.

SEGUIN. 1848.

Marc Seguin, a French engineer, distinguished as having affirmed in 1839, from a study of the locomotive-engine, the correlation between heat and "work," and as having estimated the "mechanical equivalent" of heat, labored for many years to establish the unity of the natural forces. It is interesting to observe that like Herapath, he commenced his studies in molecular physics with an inquiry into the nature of heat; and like him, was led to discard entirely the generally-received theory of a material caloric in favor of the kinetic hypothesis now universally adopted.

Nearly a quarter of a century before publishing his views on molecular forces generally, Seguin presented to Sir John Herschel a very original and suggestive communication on the probable nature of heat, which was published by the latter in the Philosophical Journal of Edinburgh for 1824. The writer infers from the compressibility of all known substances that their constituent molecules must be at a great relative distance from each other; and from the characteristic odor of most solids, that the densest and hardest substances are subject to the escape of their surface molecules, or in other words, "are capable of being evaporated." From the infinitesimal size of these escaping molecules, they of course elude all known methods of comparison or mechanical appreciation.

"In order to assign to them the condition either of a solid, a liquid, or a gas, it is necessary to suppose the existence and the combination of two forces which are sometimes *in equilibrio*, and sometimes predominate the one over the other. We shall admit then the supposition that these two forces may be the same as those which regulate the planetary system, and that the molecules of bodies are subject to circulate round one another, so that each body, though it appears at rest, has really a certain quantity of motion, whose measure will be a function of the mass and the velocity of the molecules in motion. Upon these suppositions it is obvious that during the impact of two bodies, all the quantity of motion which is not employed in giving the body which is struck a motion of translation, will go to augment the quantity of interior motion which it possesses; and if this motion takes place in circles or ellipses, the parts will recede from the center of attraction, and the body will increase in volume. In this state it will have a tendency to transmit the excess of motion which it possesses to bodies which are near it, or to parts which it will emit in greater number in following the same law. If the quantity of motion is so great that the attraction of the molecules can no longer be *in equilibrio* with their angular velocities, the body will remain in the gaseous state till it has transmitted to other bodies the excess of velocity which it possesses."*

This is a very neat and perspicuous presentation of the dynamical

* The Edinburgh Philosophical Journal, October, 1824, vol. x, pp. 280–282.

theory of temperature, expansion, conduction, evaporation, and the transformation and conservation of energy; and although three years later than Herapath's remarkable announcement of the theory of gaseous temperature, is doubtless an independent and original *discovery;* for such it is entitled to be called. There is now little question that while the molecular excursions in gases take place in straight lines or in hyperbolic trajectories, the atomic motions *within* the molecule (whose marvelous regularity of periodicity is attested by the fixed refrangibilities of the spectrum) are really described in elliptic orbits, as Seguin had so early preconceived.

The writer proceeds to apply this hypothesis to a variety of apparently unconnected phenomena, as to the sudden development of motion in the fracture of a "Prince Rupert's Drop" or unannealed glass tear; to the action of the steam-engine, in which a large amount of molecular orbital motion in the vaporized water is transformed into the rectilinear or translatory motion of the piston; for "if, as we suppose, an angular motion has been changed into a rectilineal motion or into a motion of trans lation, we should find after the effect only the quantity of motion which has not been employed in producing the useful effect." He shows that the same theory explains satisfactorily the great degree of refrigeration observed in the higher regions of our atmosphere, while by the material theory of caloric the upper regions should be the hottest; and he maintains that even "the motion produced by organized bodies may be explained in the same manner as the steam-engine." This is certainly a very remarkable prevision of the correlation between the physical and the organic forces.

It was not till 1848 that Seguin commenced a series of memoirs, read before the French Academy of Sciences, on the nature of the molecular forces, but dealing mainly with cohesion regarded as a phase of gravitative action. A theory of mutual impacts and reactions between the molecules of matter and the atoms of the æther was proposed but not very clearly presented.* With a communication, made October 22, 1849, the author submitted the results of experiments showing actions "very analogous, if not identical in their effects, with that of gravitation." The apparatus exhibited consisted essentially of a magnet attached to a pendulum which produced motion in small iron bullets suspended a short distance therefrom.

In an editorial *résumé* of Seguin's work on "Molecular Physics," in Abbé Moigno's *Cosmos*, in 1852, the Abbé, after alluding to Newton's speculations, affirms with characteristic confidence and earnestness: "If there is anything certain in the world, it is that the molecules of bodies and bodies themselves are not really self-attractive; it is that attraction is not an intrinsic but only a developed force; it is that not-

* *Comptes Rendus*, September 25, 1848, vol. xxvii, pp. 314–318; January 22, 1849, vol. xxviii, pp. 97–101; October 22, 1849, vol. xxix, pp. 425–430; January 19, 1852, vol. xxxiv, pp. 85–89; November 7, 1853, vol. xxxvii, pp. 703–708.

withstanding everything occurs as though bodies mutually attracted each other, it is incontestably true that bodies do not so attract. Newton, as Euler,—as every philosopher worthy of the name,—has seen in nature but two things, *inertia*, and *motion* originally impressed by a free Will, the first and infinite Mover. And it is with these two great facts of inertia and movement that advancing science shall ultimately explain all the phenomena of the physical world. Already courageous thinkers have endeavored to explain by inertia and motion the great, the capital fact of universal attraction, but these explanations are neither so distinctly formulated nor so plausible as to enable us to give a correct idea of them." Abbé Moigno, as Seguin's interpreter, proceeds: "The secret of cohesion has been pursued by one of our most illustrious compatriots, M. Seguin, senior, for the last twenty years, and he has certainly discovered it. It consists most essentially, as we shall proceed to show, in the incontestable fact that the molecules of bodies exceed in number and minuteness anything that could have been imagined."*

This theory of cohesion is then set forth at some length, the fundamental assumption being that there are two classes of dynamic monads occupying the universe, the one in a state of relative repose, exhibiting the various phenomena of attraction, and commonly called the ponderable elements, and the other class entirely free or independent, (improperly called imponderable elements,) actuated with extreme velocities of translation, of rotation, and of vibration, continually traversing the systems of ponderable monads in all directions.†

Although the admiring editor avows himself a pupil of Seguin, it is doubtful whether he has cautiously followed him, in so enthusiastically proclaiming his development of "a vast theory from the admission of but a single principle in the universe,—the attraction of two monads in the inverse ratio of the distance squared, without recourse to any hypothetical force of mysterious attractions or of impossible repulsions."

In 1858, Seguin published in the *Cosmos* a somewhat elaborate essay "On the Origin and Propagation of Force," in which he seems to have abandoned a kinetic theory of gravitation. It is true that he there holds: "Matter is inert; that is to say, it does not harbor in itself the power to put itself into movement, and still less *a fortiori* to communicate it, since a thing to be transmitted must first exist."‡ And it is also true that he repeatedly speaks of "the great principle of the indefinite conservation of motion" as being "the foundation of all mechanics;"§ and regards "the possibility of the destruction of motion as equivalent to "the annihilation of force,"‖ which is the very *shibboleth* of kinetic theorists; and further that he disputes Poisson's proposition that two spheres of equal mass and velocity, *devoid of elasticity*, if

* *Cosmos*, November 14, 1852, vol. i, pp. 693, 694.

† *Cosmos*, vol. ii, pp. 371-382, and pp. 625-632.

‡ *Cosmos*, October 15, 1858, vol. xiii, p. 485.

§ *Ibidem*, pp. 503, 505, 515, 518, 527.

‖ *Ibidem*, p. 509.

directly meeting, would have their motion destroyed, and be reduced to rest; maintaining that "the idea of the possibility of the destruction of force and of the complete disappearance of motion has always been insuperably repugnant to sound and careful thinkers, who have made this question a subject of study."*

Notwithstanding all which, he says, in regard to the uniform tendency of a material system to its center of gravity, "we are thus led to consider attraction *as a first cause*, emanating directly from the Divine Will in the creation of matter. Doubtless it is not impossible that it may hereafter be discovered that attraction in its turn is only a consequence of a more general law, comprehending in itself more implicitly the means of explaining the effects attributed to attraction. . . . But as these considerations are purely metaphysical, since observation cannot reach beyond the established fact that two confronting bodies gravitate toward each other by virtue of a force to which is given the name of attraction, it appears to me wiser not to advance further to penetrate a mystery which nothing within our knowledge as yet appears able to explain. Let us then consider matter as existing from the beginning uniformly in space, and attraction as an essential property with which it is endowed, by virtue of which the different parts or molecules composing it possess in themselves the power of mutual attraction."†

So explicit a statement would seem quite sufficient to prove that Abbé Moigno has in his zeal transcended the doctrines of the one whom he had effusively recognized as his teacher; and that whatever may have been the earlier views of Seguin as to the origin of gravitation, he can no longer be numbered with those who conceive it to be "a mode of motion."

BOUCHEPORN. 1849.

M. F. de Boucheporn read a memoir to the French Academy of Sciences, July 30, 1849, entitled "Researches on physical laws considered as consequences of the only essential properties of matter, impenetrability and inertia;" the object proposed being to show the considerations leading to the conclusion that all physical law rests simply on these necessary attributes of matter, "without the supposition of any *force*."

He commences with the general recognition, "It is an idea quite old in science that the movements of the heavenly bodies may be explained by an external impulsion or by the action of a universal fluid. This was the earliest idea of French philosophy, being that of Descartes, and even Newton himself had thought of connecting with it the great law of gravitation."

Boucheporn proceeds to cite some of the principles and results developed. "1st. The intensity of an impulse propagated in the æthereal

* *Cosmos*, October 15, 1858, vol. xiii, p. 508.

† *Ibidem*, pp. 486, 487.

medium follows the law of the inverse square of the distance from the center of disturbance. 2d. The resistance of the æther does not sensibly affect the velocity of a body when this is sufficiently less than that of ætherial propagation; but this resistance becomes a uniform pressure on the entire surface of a body, (supposed spherical,) and even determines its sphericity. 3d. Taking as unity the density of the fluid, the quantity of motion impressed by a body on the æther is equal to its volume multiplied by the square of its velocity; which is also the measure of the total pressure on the surface of a body. 4th. Propagated to the interior of the heavenly bodies, the pressure would produce the effect that all layers of equal thickness will inclose the same quantity of matter, and that the mean density is three times that of the surface. This kind of homogeneity would not be affected by the action of heat. In short, from such great internal condensation, it may be conjectured that the heavenly bodies are almost entirely impermeable by the æther, as will shortly appear from an astronomical law. 5th. As to attraction; the displacement of the æther by the movement of a body A, will produce in all parts of the fluid a sort of aspiration toward the point being left by its center; any other body B receiving these aspiring waves on its nearer hemisphere will have lost all or a part of its own pressure; and the half pressure (volume multiplied by the squared velocity) which acts on the opposite hemisphere, no longer being counterbalanced, will give an impulse to the body B in the direction of A. Such would be the principle of attraction. . . . "

The writer finds a verification of his principles in the relation existing between the respective *masses* of the planets and the product of their volumes by the square of their velocities, omitting the cases of Uranus and Neptune. Also by determining the velocity of an attracting body from that of its satellite, knowing only the ratio of the radius to the distance; and lastly, by determining the amount of *fall* of heavy bodies from the angular velocity of the earth, irrespective of its mass!*

LAMÉ. 1852.

Gabriel Lamé, a distinguished French geometer, and author of a very learned and valuable work on the laws of *elasticity*, embracing a profound mathematical discussion of the theory of vibrations in almost all its scientific aspects, has incidentally alluded to gravitation in such a manner as to deserve a notice here.

Of his more immediate theme he forcibly remarks: "Elasticity is the real origin or indispensable intermediary of all the more important physical phenomena of the universe. . . . In a word, the function of elasticity in nature is at least as important as that of universal gravitation. Indeed gravitation and elasticity should be considered as effects of the same cause, which correlate or connect all the material parts of the uni-

* *Comptes Rendus*, July 30, 1849, vol. xxix, pp. 108-112. The author embodied his views in a work entitled *Principe Générale de la Philosophie Naturelle*, 8vo, Paris, 1853.

verse; the first asserting this relation through immense distances, the second exhibiting it only in very small spaces."* In what way these two great master-forces of nature, seemingly so unlike, and even antagonistic to each other, may possibly be connected in action or in principle, is nowhere suggested; but the character of the author forbids the supposition that the remark was hastily ventured, or conceived without sober reflection.

No further reference however, to the subject of gravitation occurs in the work, till toward its close. In the last "Lesson," Lamé shows the necessity for admitting a pervading æther. And considering the question whether ponderable matter is really the medium which vibrates and transmits light in transparent crystals, he decides: "There can no longer exist a doubt on this question; for it clearly results from our analysis that ponderable matter alone is incapable of producing progressive waves which will explain the optical phenomena of birefractive bodies, or which could have led to the discovery of most of these phenomena. Luminous waves then are produced and propagated in transparent bodies by the vibrations of an imponderable fluid, which is no other than the æther." He determines analytically two systems of undulation in the æther, of differing velocities; one system radial, or normal to the ellipsoidal surface of the wave, affecting the dilatation or condensation of the medium, and not concerned in optical phenomena; and the other system transverse to this in two sets, or in the direction of two tangents to the ellipsoidal wave, representing the phases of polarized light.†

Lamé concludes his Lessons with some reflections on the internal constitution of solid bodies. "It seems highly probable that the progress of general physics will conduct one day to a principle analogous to that of universal attraction, of which this itself shall prove only a corollary, and which may serve as the basis of a rational theory comprehending both mechanics—the celestial and the terrestrial. But to presuppose this unknown principle, or to infer the whole from one of its parts, is to retard—it may be for a long time—the epoch of its discovery." And speaking of the great desideratum, a rational science of molecular mechanics, he asks: "Is this an enigma forever insoluble? To this question must be answered yes, if the existence of ponderable matter only is to be admitted;—no, if we admit also the existence of the æther."‡

"Since then the existence of the ætherial fluid is incontestably demonstrated by the propagation of light through celestial spaces,—by the explanation (as simple as complete) of the condition of diffraction in the theory of waves,—and as has been seen,—by the laws of double refraction, which prove with no less certitude the existence of an æther within

* *Leçons sur la Théorie Mathématique de l'Élasticité des Corps Solides.* 8vo, Paris, 1852. Lesson i, p. 2.

† *Loco citat.*, Less. xxiv, sec. 131, pp. 327, 328.

‡ *Loco citat.*, sec. 134, pp. 332, 333.

transparent bodies, we know that ponderable matter is not alone in the universe; its particles swim as it were in a kind of fluid medium. If this fluid be not the unique cause of *all* the observed facts, it must at least modify them, diffuse their action, and complicate their laws. It is then no longer possible to attain a rational and complete explanation of the phenomena of physical nature, without recognizing the intervention of this agent, whose presence is so inevitable. It is scarcely to be doubted that in this intervention, sagaciously investigated, will be found the secret or the true cause of the effects which are attributed to heat, to electricity, to magnetism, to universal attraction, to cohesion, to chemical affinities; for all these mysterious and incomprehensible agencies are at bottom but co-ordinating hypotheses,—useful without doubt to our existing ignorance, but which the progress of true science will complete by dethroning."*

These passages are less notable for any precise hypothesis as to the cause of gravitation than for their earnest unformulated faith in the mechanical agencies of the æther as the fountain-head of all force.

A very striking illustration of the author's realizing sense of the ætherial presence occurs in a memoir communicated by him to the Academy of Sciences about ten years before this time, or in 1842; in which, discussing the difference between the determination by Gay-Lussac of the co-efficient of gaseous dilatation, and that made by Rudberg and verified by Regnault twenty-five years later, Lamé made the somewhat startling announcement that the observed difference indicated an increasing æther-pressure on terrestrial matter! "The difference between these results is explained by admitting that the pressure of the æther has undergone on the earth in a quarter of a century an augmentation equal to a pressure of eight or nine tenths of a millimetre of the mercurial column."†

WATERSTON. 1858.

In an essay "On the integral of gravitation, and its consequents with reference to the measure and transfer, or communication of force, by J. J. Waterston," of Edinburgh, published in the Philosophical Magazine, the writer commences with the general consideration: "Modern ideas with relation to heat and the active condition of the molecular element naturally incline us to estimate every force with regard to its work-producing capacity. In the following paper I have considered gravitation under this aspect, and in doing so, have been led to discuss some points relating to dynamical sequence in the abstract."

After referring to the fact that neither Newton nor Laplace recognized the principle of the conservation of force in their grand researches, Waterston continues: "Even at the present day, mathematicians have been so long accustomed to and brought up in the statical method of

* *Loco citat.*, sec. 134, pp. 334, 335.

† *Comptes Rendus*, January 3, 1842, vol. xiv, p. 37.

treating molecular physics initiated by those great leaders, that the inefficiency and inconsistency of this mode of inquiry with the mechanical theory of heat seems as yet not to be fully appreciated by some even of the most zealous upholders of that theory. With this impression, it seems desirable that every effort should be made to arrive at a clear understanding of fundamental points, and the principle of physical causation, which the mechanical theory supplies."*

As this is the usual point of departure with kinematists, (*not* "brought up in the statical method,") it may be well here to affirm with some positiveness that without the ceaseless co-operation of two antagonizing or reciprocating *statical* tensions, a "mechanical theory of heat" is rationally impossible. Matter possessing only inertia and motion (whose product is momentum) would very speedily arrive at a state of stable and inert equilibrium, without having ever exhibited a single phenomenon of *force*, and without the possibility of any dynamic potential. An abstract system of kinematics, under any geometrical arrangement or conception, is indeed quite irreconcilable with the actual system of *dynamics* found in nature and subject to our observation. All gases would under the operation of the first law of motion, tend to infinite and equable diffusion; and liquids and solids would quickly follow in their wake. Heat, whether considered as a vibration or a revolution, (or preferably as both a rectilinear and an orbital movement,) could of course have no existence, since there could be neither recoil nor constraining bond; and the very first step toward an oscillation would also be the last one. Even the principle itself of "conservation of force" is absolutely dependent on the existence of primordial *static* potentiality. So much for a "clear understanding of fundamental points."

"SECTION 1. The integral of gravitation is a function of space. Suppose a central homogeneous globe to augment in bulk by the descent of similar matter from an infinite distance in radial directions all around; each descending element, on arriving at the surface of the globe, presents itself charged with a certain amount of mechanical force equivalent to the square velocity with which it impinges. If we confine our attention to the centripetal influence of the original central globe only, the square velocity of the descending element diminishes in the inverse ratio of the radius of the augmenting globular mass; for it is upon the surface of this that impact takes place, and the matter that has been added to the original globe is assumed not to augment the centripetal force acting upon the descending matter."† This established ratio of final velocity does not appear in any way to substantiate the general proposition; nor is it seen to receive support from any of the succeeding illustrations. Gravitation, as a fact of observation, is always found to be rigorously relative to two posited elements; and its integral is by such observation a function of the *distance* between these elements. If

* L. E. D. Phil. Mag., May, 1858, vol. xv, p. 329.

† *Loco citat.*, p. 330.

the distance is infinite, the integral is negatively infinite. But how it is a function of "space" in any more general sense, is certainly not obvious. As Professor Brücke, of Vienna, has forcibly said in his response to Faraday: "So far as my consciousness reaches, so far as I am capable of distinguishing true from false, and like from unlike, all known facts are brought into complete harmony with our laws of thought, when we suppose forces as the causes of phenomena to reside in the masses, the spaces between these masses being traversed by the forces. If the forces could be imagined as existing in space, it must also be conceivable that matter may be annihilated without changing the sum of the forces, and this, at least by me, is not conceivable."*

"SECTION 2. The force-generating faculty exists in space, and is directed centripetally. [?] This is proved by the following considerations. The integral force-producing power of any body, however small, subject to the law of universal gravitation, is illimitable as space. It is impossible to imagine an infinite attribute belonging to a finite entity.† It is therefore in space that the energy that contributes the power of gravitation exists, and the element of matter merely gives to it a centripetal direction. This, as a consequent of the law of gravitation, seems noteworthy from it probably being applicable to molecular forces generally. It favors the idea that the function of the material element is to give *direction* to a living force that pervades space."‡ The first part of this proposition, (as an iteration of the previous one,) that gravitative force "exists in space," is derived as an inference from a metaphysical postulate,—"It is impossible to imagine" it as belonging to a finite body. But our powers of "imagining" can hardly be accepted as the measure of scientific verity. "It is impossible to imagine" the nature of electrical action, chemical affinity, luminiferous vibration, æther, atom, force, or space! Who is able to formulate in thought the co-existence of an equal repulsive and attractive energy in either pole of a bar magnet, simultaneously discriminating by opposite action between the reversed ends of two magnetic needles? But when it is said that the sole function of the material element is to give centripetal *direction* to the circumambient ocean of force, wonderful indeed is the conception of virtue in the "finite entity" thus drawing to itself the centripetal tendency in all directions throughout illimitable space, and instantaneously re-adjusting these infinite lines of force with every momentary change of position! If difficulty of "imagining" were a criterion of error, surely it might be well applied to this hypothesis.

"SECTION 3. The law of gravitation with respect to the element of radial space, is usually defined with reference to a constant element of time; the increment of velocity generated being proportional to the increment of time, whatever the direction or velocity of the motion, and

* L. E. D. Phil. Mag., February, 1858, vol. xv, pp. 87, 88.

† Is it impossible to imagine an atom having an eternal duration?

‡ Phil Mag., 1858, vol. xv, pp. 331, 332.

inversely as the square of the central distance. If we view it with reference to a constant element of radial space, we find that the increment of square velocity generated by the force of gravitation is proportional to decrement of radial distance, and inversely as square of central distance. This holds whatever the velocity or direction of the motion, whatever the orbit of the projectile . . . ."

"SECTION 4. The mutual gravitation of two bodies develops mechanical force in each of them inversely proportional to its mass. Suppose two bodies to descend toward each other by their mutual gravitation, their common center of gravity being at rest. At any time before they meet, their acquired velocities being examined will be found inversely as their masses; which assume as one to ten. Suppose them removed to the earth's surface, and each projected up a vertical with their acquired velocities respectively: the smaller body rises 100 times the height ascended by the larger, and thus in again descending would be able to perform ten times the work . . . ."*

After some other propositions and discussions, not specially bearing on the present inquiry, Mr. Waterston gives a general statement of results as follows: "Even if we had not those proofs of the existence of a universal medium that the undulatory theory of light supplies, it would be well to admit the existence of media to which ordinary matter may be assumed to be entirely subordinate in all their potential relations, so as to give order to our ideas in tracing out the dynamical sequence of nature. It would be taking too narrow a view if we limited the function of the luminiferous æther to the conveying of physical pulses only. The atmosphere also conveys physical pulses, but that is the least important of its functions in the economy of nature. There is nothing that should hinder us attributing to the media concerned in the radiation of heat and light the higher functions of electric polarity and gravitation. The special dynamic arrangements by which this is effected may ever elude research, but as there is no limit to the *vis viva* which such media may conserve in their minutest parts, so there is no physical impossibility in that *vis viva* being suddenly transferred to the molecules of ordinary matter in the proportions and sequence required to carry out the order and system of nature. The fundamental principle of action in such media must be in accordance with *elastic impact*, for upon that the dynamic theory of heat and conservation of force rests as a foundation. The statical and dynamical characteristics of gravitation and transfusion of force have also been shown to conform to it, so that all the forces that hold the molecules of bodies together must also be in subjection to it." †

From the above it would appear that the writer in previously affirming the integral of gravitation to be a function of *space*, intended rather the content of space, or the dynamic medium supposed to occupy it. Th-

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* *Loco citat.*, p. 332.

† *Loco citat.*, p. 344.

whole suggestion is however, so indefinite that it must be accounted less a coherent hypothesis than a mere speculation,—a cast among the possibilities. To refer the great fact of gravitation to some unimagined and unimaginable æther-motion, the special arrangements of which for effecting the desired purpose "elude research," is not to proffer an explanation, but to indulge in an illusion; and although Mr. Waterston has in terms recognized all of the six propositions (excepting the last one) announced as the necessary conditions of the problem,* he has failed to show that one of these conditions can be satisfied by his speculations.

CHALLIS. 1859.

Professor James Challis, of the University of Cambridge, England, in the prosecution of a "Mathematical Theory of Heat," published in the Philosophical Magazine for March, 1859, advanced in November of the same year, to a "Mathematical Theory of Attractive Forces," based on the assumption "that all substances consist of minute spherical atoms of different but constant magnitudes, and of the same intrinsic inertia; and that the dynamical relations and movements of different substances, and of their constituent atoms, are determined by the pressures of the æther against the surfaces of the atoms, together with the reaction of the atoms against such pressure by reason of the constancy of their form and magnitudes. The æther is assumed to be a uniform elastic fluid medium pervading all space not occupied by atoms, and varying in pressure proportionally to variations of its density. The theory recognizes no other kinds of force than these two, the one an active force resident in the æther, and the other a passive reaction of the atoms."

After a formidable array of partial differential equations, the author concludes: "Having now shown that waves of large breadth *attract* a small spherical body toward their origin, and having previously shown that waves of small breadth may *repel* such a body in the contrary direction, the main difficulty in forming a theory of attractive and repulsive forces seems to be overcome."† It is supposed by Professor Challis that by the disturbance of a material element, a series of undulations differing greatly in their order of magnitude and velocity may be simultaneously propagated in the ætherial medium, giving rise to as many different manifestations of force; and that according to their relative wave-length, some of these will produce a permanent motion of translation on molecules of determinate mass subjected to their influence. This is partly in accord with the striking experiments of Guyot previously referred to.

In a following paper the author undertook "A Theory of the Force of Gravity;" remarking that, "As we have no conception from personal experience and sensation of any other species of force than *pressure*, the *actio in distans* does not admit of being explained by any previous or

* *Loco citat.*, p. 335.

† L. E. D. Phil. Mag., November, 1859, vol. xviii, p. 334.

concomitant knowledge, but if it be a reality, must forever remain to us incomprehensible." How the school-boy's personal experience of the strain exerted in drawing by a cord his winter's sled can be resolved into a sensation of "pressure" does not seem easy of discovery.

Assuming then an order of ætherial waves having a much larger range than those of light, Professor Challis endeavors to deduce the several laws, of action proportional to the number of atoms acted upon, of the inverse square of the distance of action, and of simultaneous action in different directions. He infers that if such waves encountered a slight retardation of propagation in passing through the earth, they would be refracted, so to speak, by the form of the large inequalities of the terrestrial surface, producing the observed deflection of the plumb-line.

He also supposes that a small function involving r^4 must be added to the usual formula $\frac{m}{r^2}$ increasing sensibly the action of the sun near its surface and diminishing its action notably through interstellar distances. He thinks that this alone will explain why the sidereal system does not collapse toward its common center of gravity. "According to the theory of gravity I have proposed, although the ordinary law may be exact through the solar system and far beyond, there must be distances at which the condition that the excursions of the vibrating particles of the æther are large compared to the dimensions of the atoms ceases to be fulfilled. In that case the attraction changes to repulsion."*

Renewing the discussion of "A Theory of Molecular Forces," the following year, Professor Challis contends: "It is a matter of demonstration that a theory of molecular forces cannot be constructed on the hypothesis that the forces vary according to some law of the distance from individual material particles, unless the law be such that the force changes sign with the distance so as to become attractive after being repulsive. But if force be a virtue resident in the particle, it must *at its origin* be either attractive or repulsive, and it seems impossible to conceive how by emanation to a distance it can change its quality. This difficulty, as will be shown, is not encountered in a theory of molecular forces which deduces their laws from the dynamical action of an elastic medium." While it is probably no more difficult to conceive an innate force or virtue which "at its origin" shall have a law of radial intensity whose value passes through zero, than to conceive any other mathematical law of increment or decrement, there is certainly no necessity for assuming such a law. If we should suppose the attraction by inverse squares to be *absolute*, with the superposition of a repulsion of much higher inverse power, and of far greater intensity, it is evident that the two curves of force would cross each other, and that at the intersection the resultant would involve a "change of sign." However difficult it may be to realize such a conception, the actual superposition of oppos-

* Phil. Mag., 1859, vol. xviii, p. 451.

ing forces is daily exhibited to us in the behavior of the magnet. Another possible conception is that repulsion is a positive material or ætherial atmosphere of definite radius.

Indeed, the author's theory is really one of the superposition of two systems of waves, rather than one of a single system changing its sign. For he supposes that the attraction of gravity results from ætherial waves of great length and correspondingly large excursions or amplitudes, in which the diameter of the material atom is a vanishing quantity ("$\mu=0$"), and there is no sensible difference between the velocities on its two hemispheres; while atomic repulsion results from such small waves (smaller even than those of light) that the atom is large in comparison, and the difference of the wave on its two hemispheres is very notable. "Thus the conditions assumed in the mathematical theory of heat are satisfied by supposing μ to be very large and q [the excursion of the wave] to be very small; and the fulfillment of these conditions accounts for the great energy of calorific repulsion. . . Hence atoms of very small size, acting upon each other by the intervention of waves of which the excursions are very small, mutually repel with a very great force; and at the same time, as was shown in the Theory of Heat, the force varies very rapidly with the distance."

Attributing to the spherical hard atom of matter only inertia, "it would be contrary to these principles to ascribe to an atom the property of elasticity, because from what we know of this property by experience it is quantitative, and being most probably dependent on an aggregation of atoms, may admit of explanation by a complete theory of molecular forces." * Of this fundamental property however,—necessarily precedent to all theory of wave-action,—no explanation is given.

That the author did not feel entirely satisfied with his vibratory theory of molecular forces, would appear from his returning to the subject two years later with the remark: "Such vibrations, when we calculate their effect only to the first power of the velocity, are found to produce simply oscillations of small spherical bodies submitted to their action, and not motion of translation. To account for the latter, it is necessary to proceed to the consideration of effects due to the second power of the velocity. . . . . . Lastly, there is yet another physical force, the relations of which to an ætherial medium and to other modes of force are not readily made out: I mean the force of gravity. If however, all the other forces are modifications of ætherial pressure, it is reasonable to suppose that this one is of the same kind. I have ventured to reason on this supposition, and have attempted to deduce (I think with success) the known laws of gravity from the dynamical action of ætherial waves of much larger magnitude than those which correspond to molecular forces." †

While it is comparatively easy to explain the origin of heat-waves

* L. E. D. Phil. Mag., February, 1860, vol. xix, pp. 89-91.

† L. E. D. Phil. Mag., April, 1862, vol. xxiii, pp. 319, 320.

by the theory of the reactions of antecedent *forces*, the converse problem, to explain forces by the hypothesis of antecedent waves, is by no means so simple. Accordingly, a very weak point in all undulatory theories of gravitation has been an account of the *origin* (to say nothing of the continuance) of the *primum mobile*. "On the source and maintenance of the sun's heat," Professor Challis remarks as follows: "We are led to the conclusion that the undulations which emanate equally in all directions from each atom, and constitute by their dynamic action the repulsion of heat, are mainly produced by the reaction of the atoms due to their inertia and impenetrability. It is plain however, from this reasoning, that there must be an original and independent source of undulations. Now obviously such a supply may be conceived to be furnished to the sun *by undulations emanating from the stars*. We have ocular evidence that stars transmit light-undulations, and it is quite possible that they originate others not sensible to the sight."* As our sun is one of the stellar fraternity, surely this device of mutual borrowing is an extraordinary method of production.

"That action at a distance is not a universal condition of force is proved by the modern discovery that light and heat, which are modes of force, are transmitted through space by the intervention of a medium. If one kind of force requires a medium of transmission, why not another? Again, it is found by experience that the same portion of matter may attract or repel, according to circumstances. But inherent force cannot possibly be so changed by circumstances. In the same matter it must continue to be always the same."†

"All physical force being pressure, there must be a medium by which the pressure is executed." And the origin of this pressure is therefore, the origin of "all physical force." The fundamental postulate of this medium is that it is a uniformly continuous elastic fluid, exerting a pressure always proportional to its density. As it is contrary to principle to ascribe elasticity to atomic matter, the question might arise, why is it more proper to ascribe this occult property to the *æther*? In the case of air (of uniform temperature) the constant ratio of pressure to density results we are told, from a *vis a tergo*, the vibratory action of the interstitial *æther*. The author perceives the incongruity of denying to the air a quality attributed to the æther, when the law is implicitly the same in both; and he suggests in extenuation, "we can conceive of the existence of another order of æther having the same relation to the first as that has to air, and so on *ad libitum*."‡

The very key-note of the hypothesis is dynamic ætherial "pressure." "All the different kinds of physical force detected by observation and experiment are modifications of *pressures* of the æther."§ But when we

* Phil. Mag., June, 1863, vol. xxv, p. 465.

† Phil. Mag., October, 1863, vol. xxvi, p. 284.

‡ Phil. Mag., June, 1866, vol. xxxi, pp. 468, 469.

§ *Ibidem*, p. 470.

seek the cause of this pressure, it forever eludes us. Here then the system stands self-convicted of impotence to exercise its prime prerogative. At whatever point in the infinite series of descending orders of æther we stop, the secret of its power is ever one step backward. We must still "conceive of the existence of another order of æther having the same relation to it" that it had to the preceding. And that no possible element of embarrassment may be wanting to our conception, the first æther is absolutely "continuous," without atoms and without interstices!

In 1869, Professor Challis published an elaborate extension of his mathematical discussion of kinetic theories of the physical forces, in a large octavo volume of some 750 pages; the first half of the work being devoted to a general mathematical treatise, of high merit and value, under the title of "Notes on the Principles of Pure and Applied Calculation." In the latter portion of the work, (on theoretical physics,) the subjects treated of "are those of light, heat, and molecular attraction, force of gravity, electricity, galvanism, and magnetism, respecting which I make the general hypothesis that their phenomena all result from modes of action of an elastic fluid, the pressure of which is proportional to its density."* And in the "introduction" to the work, he has more explicitly stated: "The hypothesis respecting the æther is simply that it is a *continuous* elastic medium, perfectly fluid, and that it presses proportionally to its density."† The forces of elasticity, and of chemical affinity, are excluded as beyond the present reach of analysis.

A distinction is made between the ætherial radiations of light and of heat, not justified by any observed phenomenon. "Since in the theory I have proposed, the transverse vibrations of rays always accompany direct vibrations, and it was concluded that the sensation of light is entirely due to the former, we are at liberty to refer the action of heat, or other modes of force, to the direct vibrations."‡ This would leave the polarization of heat quite inexplicable; as obviously vibrations of the acoustic type are incapable of polarization.

It is now familiar to opticians that fine rulings on glass, whose distance apart is less than a half of the wave-length of light, are readily resolvable with optical distinctness by our modern microscopes, while the intimate texture of the glass is apparently as far removed from resolution as with the unarmed eye. What part can ætherial vibrations play in giving cohesion to the ultimate molecules of the glass? Here then is apparently a new difficulty for the undulatory theory of force; for not only are the ultimate molecules of the silicate bound together with a powerful force, (giving seeming continuity of substance to our highest artificial vision,) but they are also held apart with a still more potent stress. Professor Challis does not shrink from the solution.

* Principles of Mathematics and Physics, 8vo., Cambridge, 1869, p. 318.

† Introduction, p. xlv.

‡ *Opere citat.*, p. 437.

"Making the only hypothesis which is consistent with the theoretical principles advocated in this work, namely, that the ultimate atoms of the glass are kept asunder by the repulsive action of ætherial undulations which have their origin at individual atoms, it may be presumed that this atomic repulsion is attributable to undulations incomparably smaller than those which cause the sensation of light. . . . The only additional hypothesis that will now be made is that there are undulations of the æther for which the values of λ are very much inferior in magnitude to those of the undulations which produce the phenomena of light. The origin of this class of undulations may, as well as that of all others, be ascribed to disturbances of the æther by the vibrations and motions of atoms. Although the periods of the ætherial vibrations may, under particular circumstances, be determined by the periods of the vibrations of the atoms, this is not necessarily the case. . . ."*

"However small may be the condensation propagated from a single atom, the resulting condensation from an *aggregation* of atoms contained in a spherical space will be of sensible magnitude at distances from the center of the space very large compared to its radius, provided the space be not less than a certain finite magnitude, and the atoms contained in it be not fewer than a certain finite number. . . . We have hitherto had under consideration the waves of atomic repulsion and the waves of molecular attraction, and it was argued that the latter might result from compositions of the former, and that in that case the values of λ would be much larger for the composite waves than for the components."†

In 1872, the author again writing "On the Hydrodynamical Theory of Attractive and Repulsive Forces," says in regard to the discussion of the first and second orders of small quantities, "Having in fact succeeded in overcoming the mathematical difficulty of effecting a second approximation by this means, [starting from the first approximation,] I have ascertained that the solution contains terms of indefinite increase, whence it must be concluded that the logic of the process is somewhere at fault. . . . Both in this Magazine and in my work on the Mathematical Principles of Physics, I have in various ways attempted to solve to the *second* approximation the problem of the motion of a small sphere acted upon by the vibrations of an elastic fluid. But I must confess that owing to the difficulty of including the effect of the spontaneous vibrations, my efforts have been only partially successful." He remarks that as his equations involved two unknown constants H_1 and H_2, (representing the amounts of wave condensation on the nearer and on the further hemispheres of the atom,) "on this account the theories which attribute the forces of *heat*, *molecular attraction*, and *gravity*, to action on the atoms by pressure of the æther in vibration, are incomplete." And he admits that for any purpose of quantitative determina-

* *Opere citat.*, pp. 456, 459.

† *Opere citat.*, pp. 463, 489.

tion or verification, "The whole theory however of attractive and repulsive forces, regarded as due to vibrations of the æther, is incomplete for want of an *a priori* determination of the composition and value of the quantity *H*."*

In 1876, the author returns to the discussion with a view "to correct in certain respects that investigation, [the one last cited,] and to carry it a step further." And in dealing with a residual effect of vibration, "which in fact is the *attraction of gravity*," and determining that the accelerative force is independent of the size of the atom or molecule, he says: "This result expresses *the force of gravity* as due to the attractive action of a molecule of a higher order as to magnitude than the molecule of *molecular* attraction. For distinction, a molecule of this superior order might be called a *gravity-molecule*. Its magnitude may still be considered to be so small that in comparison with the magnitudes of terrestrial and cosmical masses, it may be treated as an infinitesimal quantity. . . . . Lastly, it is to be noticed that on account of the large value of λ for gravity-waves, they do not suffer sensible retardation or refraction in passing through gross bodies. I have on several previous occasions, treated of the problem of gravitating force theoretically, and by slow steps have approximated to its solution; but before the present attempt, I had not succeeded in exhibiting satisfactorily the *rationale* of this kind of attraction by vibrations."†

Such is an imperfect abstract of the most carefully-studied and the most diligently-elaborated exposition of the wave-theory of attraction which has yet been proffered to the scientific world. Discussed with the earnestness and candor of a fervent conviction, and with all the resources of a high order of mathematical culture and ability, the result yet fails, sadly and fatally, to satisfy the conditions of the problem. Strong as is the author's assurance that he has successfully grasped by his formulas and equations the several functions embraced in the first three of our propositions,‡ this is by no means mathematically established; and the last three propositions are hopelessly ignored and violated. We have seen that *Elasticity*, that puzzling "occult quality," driven out from the sober presence of the purely rational atom, has in an inexplicable manner, slipped in by the back-door of ætherial pressure.

Naturam expelles furca, tamen usque recurret,
Et mala perrumpet furtim fastidia victrix.

With the multitudinous duties imposed upon the much-suffering æther, in all the varying ranges and orders of undulations derived from atoms and from molecules with ever-changing motions, amid all the perturbations and transformations of the mechanical energy of matter,

* L. E. D. Phil. Mag., September, 1872, vol. xliv, pp. 203, 204, 209.

† Phil. Mag., September, 1876, vol. ii, p. 191.

‡ Principles of Mathematics and Physics, p. 499. In the concluding chapter of the work, the author draws strength and encouragement from a quotation of the celebrated "Third Letter to Bentley."

there is one resultant alone which never by any accident incurs a composition or experiences a commutation, the constant and unchangeable undulation of gravitation.

GLENNIE. 1861.

Mr. J. S. Stuart Glennie, in 1861, published in the Philosophical Magazine several papers on the subject of gravitation, in which he proposed to show that universal *repulsion* is the true explanation of this force; thus referring it rather to a static than a kinetic condition of pressure. In an essay "On the Principles of the Science of Motion," he sets out with the design "in this attempt to found a general theory, cleared of æthers and fluids, of properties and virtues." Commencing with the generalization that "a mechanical force, or the cause of a mechanical motion, we know to be in general the condition of a difference of pressure," he infers, "hence it appears that if a general mechanical theory is possible, the ultimate property of matter must be conceived to be a mutual repulsion of its parts, and the indubitable Newtonian law of universal attraction be deduced herefrom, under the actual conditions of the world. The general experimental condition of the fitness of the mechanical conception of pressure as the basis of a general physical and chemical theory evidently is that there be a plenum. . . . . To give distinctness to this idea of the parts of matter as mutually repulsive, a molecule, or a body (an aggregate of molecules), is conceived as a center of lines of pressure; the lengths and curves of these lines are determined by the relative pressure of the lines they meet; and lines from greater are made up of lesser molecules and their lines, and so on *ad infinitum*. In speaking of a molecule or body as such a center of pressure, it will be convenient to have a technical name. Rather than coin a new term, it is proposed to use 'atom' in this sense. . . . . Atoms, or mutually determining centers of lines of pressure, may also be defined and their relations analytically investigated, as mutually determining elastic systems with centers of resistance. This is the fundamental conception (not hypothesis) of the theory. . . . . Now in a system of atoms as above defined, let the centers be of equal mass and at equal distances; there will be no difference of pressure on any one center, no moving force will be developed, and the conditions of equilibrium will be satisfied. But it is clear that forces will be developed, or the general conditions of motion be fulfilled, either (1) by a difference in the masses of the centers, or (2) by a difference in the distances of the centers, in consequence of a displacement of any one of them, or (3) supposing a state of dynamic equilibrium established in the system by its being brought in contact with another system in a different state of such equilibrium. . . . ."

"If all the masses of the system were equal, and all at the same distance from each other, their mutual repulsions would be equal in all directions, and they would remain at rest. But if, though two masses may be equal, either has on the other side of it a mass of greater size, or at a greater distance than the other, it is evident that the mutual pressures of these two equal masses will under such conditions, be unequal, and hence as in the first case, they will approach. It is also evident that a body may thus cause the approach to itself of another body, whatever the number of interposed bodies. Thus if the conception of atoms is applied to the unequal and unequally-placed bodies of such a world as that presented to us, the law of universal attraction follows, and gravity is mechanically *explained*, that is, is referred to a mechanical conception. But it must be understood that the above proposition is given rather to show that as an actual law, universal attraction may be deduced from the theoretical conception of universal repulsion, than with any pretension to its being the best attainable form of an explanation of the law. It may however be remarked that such an explanation is in accordance with the chief characteristics of the force of gravity; it is not polar, and it seems to be so far different in kind from other physical forces that it is not interchangeable with them, as they are among each other; for the attraction of gravity is thus referred to difference of mass, either between the two attracted bodies or in the systems of which they are parts."*

In a second article, "On the Principles of Energetics," Mr. Glennie proceeds: "As force is thus conceived, not as an absolute entity acting upon matter, but as a condition of the parts of matter itself, and as a condition determined by the relative masses and distances of these parts, any valid hypothesis of a force or of a motion to account for any set of phenomena is thus seen to imply an assertion as to relative masses and distances which can be more or less readily submitted to experiment or observation and analysis. . . .

"The condition of the beginning of motion is a difference of pressure on the body that begins to move; the condition of a uniform continuous motion is a neutralization of the resisting pressure; the condition of an accelerated continuous motion is a uniform or varying resisting [effective?] pressure."†

In a subsequent paper, in continuation of the last, the writer thus resumes his statement: "Here more clearly to express the idea in contrast with the fundamental hypothesis of Professor Challis, an atom may be defined as a center of an *emanating* elastic æther, the pressure of which is directly as the mass of its center, and the form of which depends on the relative pressures of surrounding atoms. Thus if you will, matter may be said to be made up of particles in an elastic æther. But that æther is not a uniform circumambient fluid, but made up of the mutually determining æthers (if you wish to give the outer part of the atom a special name) emanating from the central particles. And these central particles are nothing but what (endeavoring to make my theory clear by

* L. E. D. Phil. Mag., January, 1861, vol. xxi, pp. 41–45.

† *Loco citat.*, April number, p. 276.

expressing it in the language of the theories it opposes) I may call ætherial nuclei. . . . In defining atoms as centers of pressure, they are thus no less distinguished on the one hand from centers of force than from the little hard bodies of the ordinary theories; for such centers of force are just as absolute and self-existent in the ordinary conception of them as those little bodies; and in a scientific theory there can (except as temporary conveniences) be no absolute existences, entities. Hence (mechanical) force, or the cause of motion, is conceived not as an entity but as a condition,—the condition namely of a difference of pressure; and the figure, size, and hardness of all bodies are conceived as relative, dependent, and therefore changeable. There are thus no *absolutely* ultimate bodies."* In a later part of the same article (p. 356) the writer objects to the ordinary atomic conception that "an hypothesis of infinitely hard atoms not merely requires in the consideration of the motion of such an atom abstraction to be made of the interior relative motions, also consequent on that difference of pressure which causes its external relative motion, but explicitly denies any internal motion." The force of the objection is not very obvious. There seems to be no more need of conceiving internal motions in the ultimate unit of matter, for the purposes of molecular physics, than there is for conceiving internal motions in the planets for the purpose of astronomical physics.

In a brief summary of his views, in the succeeding volume, Mr. Glennie thus recapitulates: "Matter is conceived as made up, not of an elastic æther and inelastic atoms, but of elastic molecules of different orders as to size and density. If a rough physical conception of these molecules be required, they may be conceived as ætherial nuclei, the æther of the nuclei of a lower being made up of nuclei of a higher order, and so on *ad infinitum*." †

It is somewhat difficult to criticise a scheme of gravitative pressure so indeterminate in detail. The very function of a theory or hypothesis is to formulate the unknown in terms of the known; and in proportion as a writer fails to do this, he fails to present us with an intelligible theory or hypothesis. From the objection expressed, that "atoms" are ordinarily conceived as self-existent bodies, while "in a scientific theory there can be no absolute existences or entities," it might be supposed that the author held the constituents of matter to be merely mathematical points (without dimension) forming the centers of repulsive spheres, "ætherial nuclei;" but when we learn that these elastic molecules are "of different orders as to *size* and density," built up of successive aggregates from the infinitely small, and that each exerts a repellant "pressure which is directly as the *mass* of its center," we are led to conclude that these "ætherial nuclei" do possess a determinate magnitude. If they are not to be considered as "absolute existences or entities," they are supposed to have at least sufficient substance to be moved

* Phil. Mag, May, 1861, vol. xxi, pp. 351, 352.

† Phil. Mag., July, 1861, vol. xxii., p. 62.

about according to the differences of pressure to which they are exposed. A system composed of any number of these repellant centers having equal mass, and placed at an equal distance apart, will it is said remain in a condition of stable equilibrium, apparently whatever be the unit of distance. What fact of observation this deportment illustrates is not stated. But if either masses or distances be unequal, motion will result, and "forces will be developed." This certainly does not represent any ascertained fact of gravity or molecular physics. With a universe filled with such centers of repulsion energetic *inversely* as the square of their radii, it is not easy to see how strictly centripetal motions can result, or how such motions of approach (if possible) could exhibit an energy in directly the reverse ratio.

In enthroning a universal *repulsion* to discharge the office of a universal attraction, Mr. Glennie has not been successful in satisfying any of the conditions of the problem, and in investing his "atoms" with the pressure of *elasticity* he has hardly carried out his programme of a theory "cleared of properties and virtues."

KELLER. 1863.

Messrs. F. A. E. and Em. Keller, in a joint "Memoir on the Cause of Weight, and of the Effects Attributed to Universal Attraction," (presented to the French Academy of Sciences March 23, 1863,) announced as the motive force the agency of ætherial undulations. Referring the effect to the *longitudinal* vibrations of the æther, the writers think "the time has come to seek and to find a plausible explanation of weight—simple and natural—in the ceaseless action of these waves on resisting bodies, an action analogous to that of ocean-waves, which drive ships upon the coast by the *vis viva* of their flow over that of their ebb; for the longitudinal vibrations of the ætherial waves condensing and dilating being simply impulsions followed by reaction, and the reactions being always more feeble than the impulsions, there follows definitively an excess of force in the direction of the propagation which should communicate itself to dense bodies opposed to their propagation, and which should press them one toward the others. It is thus that inert bodies of slight density would transmit their impulsion to denser bodies, when thrown promiscuously into a long box, were we to strike repeatedly one of the ends of the box. Ultimately the denser particles will collect at the opposite end; and if both ends are struck simultaneously these particles will collect in the middle of the box, while the others will be arranged in the order of decreasing density from the center."

After considering the effect on a *line* of particles subjected to continuous shocks at each extremity, the writers proceed: "If instead of a single line of particles a certain *volume* be taken, and if instead of shocks in two opposite directions the shocks are supposed to be given in all directions, it is easy to see that the denser particles, mutually absorbing a part of the impulses directed from one to the other, would approach as if really attracted. As a resultant of all the impressions, the particles would act upon each other in the inverse ratio of the square of the distance, and in the direct ratio of their number,—an action which at once presents a striking analogy with the law of universal attraction."*

It is not believed that either of these ratios would be even approximately attained. It will be observed that in this scheme the ætherial vibrations are supposed to exert a precisely opposite action to the undulations exhibited in the system of Professor Challis, having their origin on the circumferences of enormous spheres of æther, and being accurately directed to a central point or points, whatever may be the variety of distribution or the changes of position in the material elements.

TAIT. 1864.

The professor of natural philosophy in the University of Edinburgh, P. G. Tait, has expressed himself with a cautious moderation on the probable origin of gravity, but with a sufficient distinctness to indicate his inclination to a kinetic hypothesis. In an able though somewhat prejudiced and partisan review of "The Dynamical Theory of Heat," published in the North British Review for February, 1864, after the very distinct affirmation of the great truth that "natural philosophy is an *experimental* and not an intuitive science: no *a priori* reasoning can conduct us definitely to a single physical truth;" the reviewer thus proceeds to suggest his inductive conclusions:

"In the physical world we are congnizant of but four elementary or primordial ideas, beside the inevitable *Time* and *Space*. They are *Matter*, *Force*, *Position*, and *Motion*. Of these, motion is simply change of position; and force is recognized as the agent in every change of motion. Till we know what the ultimate nature of matter is, it will be premature to speculate as to the ultimate nature of force; though we have reason to believe that it depends upon the diffusion of highly attenuated matter throughout space."†

Indefinite as the statement is, the indication that "force" probably depends rather on "highly attenuated matter" than on ordinary gross or sensible matter would appear to be derived from a somewhat metaphysical reason to believe. If the conception of a material connecting-link throughout space may be supposed to rest on a perception of physical fitness or necessity in such a transmitter of energy, this gives no physical reason to believe the origin of force resident in the one form of matter rather than in the other. For whether this "highly attenuated matter throughout space" is supposed to act statically or kinetically, and whether its function be to give or to receive impulses, we are cor-

* *Comptes Rendus*, vol. lvi, pp. 531, 532.

† North British Review, February, 1864, vol. xl, art. ii, p. 22 of Am. edition. This essay, with another one on "Energy" in the same periodical, has been republished as a separate treatise, under the title of "Sketch of Thermodynamics." 8vo., Edinburgh, 1868.

rectly informed that "force is recognized as the *agent* in every change of motion;" and therefore we are no nearer the source of this agency after the acceptance the hypothesis than we were before it.

Still more recently, Professor Tait, in an evening lecture on "Force," delivered September 8, 1876, before the British Association at its Glasgow meeting, has recurred to his kinetic hypothesis. "Why two masses of matter possess potential energy when separated, in virtue of which they are conveniently said to attract one another, is still one of the most obscure problems in physics. I have not now time to enter on a discussion of the very ingenious idea of the ultramundane corpuscles, the outcome of the life-work of Le Sage, and the only even apparently hopeful attempt which has yet been made to explain the mechanism of gravitation. The most singular thing about it is that if it be true, it will probably lead us to regard all kinds of energy as ultimately kinetic.* And a singular quasi-metaphysical argument may be raised on this point, of which I can give only the barest outline. The mutual convertibility of kinetic and potential energy shows that relations of equality (though not necessarily of identity) can exist between the two; and thus that their proper expressions involve the same fundamental units, and in the same way. Thus as we have already seen that kinetic energy involves the unit of mass and the square of the linear unit directly, together with the square of the time unit inversely, the same must be the case with potential energy; and it seems very singular that potential energy should thus essentially involve the unit of time, if it do not ultimately depend in some way on energy of motion."†

This is the unavoidable inference of the kinetic system of force, if consistently maintained. But if there be any induction *impregnable*, as the generalization of a life-long, a continuous, and an unvarying experience, it is that potential energy does *not* "involve the unit of time." The carbon that has lain protected in the bowels of the earth for untold ages (certainly for many millions of years) has precisely the same relation to oxygen as the carbon prepared from last year's wood, and holds stored in the same mass the same exactly measurable potential energy. The stone ball that may have lain a thousand years undisturbed on the brink of a precipice has during that time lost no fraction of its static tension, but will fall with absolutely the same dynamic effect as if thrown up to its seat by a cannon but a moment before. The familiar case of a wound-up clock or watch, with the pendulum or the balance-wheel at rest, is equally irreconcilable with any scheme of kinetic action or of a force involving as a function any "unit of time." As Professor Maxwell points out: "In both cases, until the clock or watch is set agoing, the existence of potential energy, whether in the clock-weight or in the watch-spring, is not accompanied with any visible

* This was, of course, its very purpose.

† Nature, September 21, 1876, vol. xiv, p. 463.

motion. We must therefore admit that potential energy can exist in a body or system all whose parts are at rest."*

The degree of accordance between the logical conclusion and the unreasoned fact, is a measure of the value of the "singular quasi-metaphysical argument" by which it is deduced. "In dealing with physical science, it is absolutely necessary to keep well in view the all-important principle that nothing can be learned as to the physical world save by observation and experiment, or by mathematical deductions from data so obtained."†

SAIGEY. 1866.

The following presentation of the theme, though from a *litterateur* rather than a *physicist*, is interesting as showing what may be called the percolation of ideas. In a series of essays contributed by Émile Saigey (under the *nom de plume* of "Edgar Saveney") to the *Revue de Deux Mondes* for November 1, November 15, and December 15, 1866, the writer proposed to give a popular exposition of "Modern Physics and Recent Views on the Unity of Natural Phenomena." After a brief sketch of the received correlation of forces, he proceeds: "What then is *gravity?* What is that mysterious force which causes two bodies to attract each other in the direct ratio of their masses and an inverse ratio of their distance? Two bodies attract each other! Then matter is not inert! Is there not then an apparent contradiction between the two terms, matter and inertia? . . . Now what light is this new theory going to throw upon the principle of gravity? Here is the answer. A substance to which the name of æther has been given is diffused throughout the entire universe. It envelops bodies and penetrates into their interstices. The existence of this substance is deduced from a series of proofs, among which luminous phenomena hold the first rank. Æther is composed of atoms which impinge upon each other and upon neighboring bodies. It forms in this way a universal medium which exerts a constant pressure upon the molecules of ordinary matter. . . . It becomes evident that bodies do not owe their gravity to an intrinsic force, but to the pressure of the medium in which they are immersed. The motion of heavy bodies no longer appears to us other than as a transformation of the ætherial motions; and gravity henceforth enters into that majestic unity to which we have conducted all physical forces. . . . Are there then strictly speaking, *two kinds* of matter? We can hardly conceive it, now that we have resolved everything into motion. In what respect would these two kinds of matter differ? Would not the one be subject to the same laws of motion as the other? Can there be two systems of mechanics? Certainly not; since there is but one law for motion, there can be but

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* Theory of Heat: by J. Clerk Maxwell, London, 1872, chap. xxii, p. 282.

† Nature, 1876, vol. xiv, p. 460.

a single essence for matter, and the molecules of ordinary matter must appear to us as aggregates of ætherial atoms."*

In his concluding essay, M. Saigey thus expounds the ætherial action: "Let us imagine the æther uniformly diffused throughout space. Its atoms endowed with motions of progression and rotation, strike each other in the manner mentioned. Let us now suppose that at some point within the medium there is a special and disturbing cause, as for example, a molecule having weight [inertia ?] and itself endowed with a vibratory motion. The disturbance goes on extending throughout the ætherial mass, and by reason of the nature of this medium is propagated in all directions. The atoms nearest to the heavy molecule will receive violent shocks; they will be powerfully urged and their ranks will grow thin in the neighborhood of the center of disturbance, and the layer contiguous to the molecule will become less dense than the rest of the medium. The motor action continuing, this same effect becomes propagated from layer to layer throughout space. As a final result, the æther becomes arranged around the center of disturbance in concentric layers, the first of which and nearest to the molecule will be least dense, and they will go on indefinitely increasing in density. This condition of things might be easily represented and the figure traced: the molecule at the center, around it spheres of atoms, wide apart at first, then nearer and nearer to each other. Let us remark, in passing, that the difference in density of contiguous layers, like all effects which are propagated by concentric spheres, is inversely proportional to the surface of these spheres, that is to the square of their radii. [?] This established, suppose a second molecule to be situated at any point of this system. It will encounter on the side toward the first molecule, layers of æther less dense than upon the opposite side: pressed upon by the æther in all directions, it will however receive fewer shocks on the side toward the first molecule, and it will consequently tend to approach it. Such would seem to be the cause of gravity."† The law of inverse squares does not appear to be well made out, although this is a point to which all kinetic theorists make ostentatious reference. The density of the æther, instead of following this ratio, should *ex hypothesi*, follow directly the opposite ratio; or rather the ratio of increase directly as the distance;—which is perhaps what was intended. Of the other five conditions it is quite unnecessary to speak.

CROLL. 1867.

In a communication to the Philosophical Magazine, in 1867, by James Croll, of Edinburgh, "On certain Hypothetical Elements in the Theory of Gravitation," the author revived the difficulties which had been felt and proclaimed by Faraday. He says: "It was demonstrated by Newton, and has been proved by general observation and experience, that

* *Revue de Deux Mondes*, 1st November, 1866, vol. lxvi, pp. 148, 149.

† *Revue de Deux Mondes*, 15th December, 1866, vol. lxvi, pp. 922. 923.

bodies tend toward each other with a force varying inversely as the square of the distance, and directly as the mass of the bodies. But it never was demonstrated or proved by any one that the bodies *attract* each other. The thing which has been demonstrated is that B tends toward A; but the theory does not rest here; it goes on to account for this tendency by referring it to a hypothetical cause, viz, to the 'attraction' of A. This however is a mere hypothesis, and no way essential to the theory. All that the theory requires is that it be demonstrated that A tends to move toward B. It is not necessary that we should go beyond this, and attempt to explain the cause of this tendency. Trifling as this assumption included in the theory may at first sight appear, it will be found that almost all the difficulties and objections which have been urged against the theory of gravitation are due in some form or other to that assumption. At the very outset we have the objection urged against the theory that it implies the absurdity of action at a distance. Now the mere facts of gravitation imply no such thing. That A and B placed at a distance should tend toward each other does not imply action at a distance. A moves by virtue of a force, but it does not follow that this force is at a distance from A. But if we assert that A and B 'attract' each other, then we imply action at a distance; for A is then affirmed to move in consequence of the force of B, and B in consequence of the force of A. 'The very idea of attractive force,' as Professor Brücke remarks, 'includes that of an action at a distance.' No principle will ever be generally received that stands in opposition to the old adage, 'A thing cannot act where it is not,' any more than it would were it to stand in opposition to that other adage, 'A thing cannot act before it is, or *when* it is not.'" *

These venerable "adages" are about as valuable in directing us to the actual facts of nature, as that other celebrated adage of Zeno, "a body cannot *move* where it is not;" and conversely, "it cannot move where it is." An equally profound dictum is, that a "cause" cannot properly be said to precede its "effect," since succession implies discontinuity.

It *may* be a fact of natural law that *everything* "acts where it is not," including even an ætherial vibration; and certainly there is no difficulty in believing it; and the other metaphysical axiom may be easily discredited by the simple reflection, that were our sun suddenly blotted from existence by supreme power, though all "attraction" of the planets would instantly cease, its full *dynamic* action on the earth would continue unimpaired for eight minutes. Were Sirius annihilated this year, it would still continue to pour upon us its full measure of dynamic action for twenty years "when it was not." The difficulty is not in the possibility of posthumous action, but in the possibility of annihilation.

As Mill has very properly stated in answer to Sir William Hamilton, "Action at a distance is intrinsically quite as credible as action in con-

* L. E. D. Phil. Mag., December, 1867, vol. xxxiv, p. 450.

tact, and there is no reason, apart from specific experience, to regard the one as in any respect less probable than the other." *

In our profound ignorance of all beyond the ascertained facts of gravitation, there could be no objection whatever to the substitution of the word "tend" for the word "attract," did it adequately express the observed fact that A *induces* in B a "tendency" to approach; the quantity of tendency in B being found to be proportional not merely to its own mass, but notably to the mass of the distant body A.

Mr. Croll proceeds: "The attraction theory is also in opposition to the principle of the conservation of force, as has been shown, I think clearly, by Faraday. When a stone for example is thrown upward from the earth, it not only loses all its motion, but it loses its attraction in proportion to the square of its distance from the center of the earth. What becomes of the motion imparted to the stone? It is not transformed into attraction, for the attraction diminishes as well as the motion. When the stone again falls to the earth it gains both motion and attraction. In the former case, the attraction is said to consume the motion, and instead of becoming stronger becomes weaker in consequence; and in the latter case it imparts this same motion, and yet after imparting the motion, it is actually found not only not to have lost but to have gained force thereby. Faraday justly asks what becomes of the force or motion imparted to the stone? It is not converted into attraction, for the attraction becomes less instead of greater in consequence. And in the case of the falling stone, where does the motion come from? If the motion arises from the attraction of the earth, then there must be a certain amount of this attractive force converted into motion; and if so, the attractive force should be so far reduced; but instead of this it is actually increased. There is therefore no account given of what becomes of the motion externally imparted to the stone when thrown upward, or whence the increase both of attraction and motion is derived as it descends. If the attraction theory be correct, then there is a destruction of force in the one case and a creation of force in the other; and if so, then the conservation of force is violated." †

Although this is merely a more prolix statement of the objection urged by Faraday, it may be again specifically answered. It will be found on careful examination, that the whole difficulty really proceeds from an hypothesis tacitly adopted by the writer, while ostensibly opposing "certain hypothetical elements in the theory." From the necessary limitations of language, we have constantly to make words do double or multiple duty in carrying different ideas; and to many this is a source of constant confusion and misconception. The tacit assumption underlying this supposed violation of the conservation of "force" is that the force of gravity is the same in kind as the force of the fall-

* Examination of Sir William Hamilton's Philosophy, by John Stuart Mill, chap. xxiv, vol. ii, p. 245, of Am. edition.

† L. E. D. Phil. Mag., 1867, vol. xxxiv, p. 451.

ing stone; and that as the latter is an example of kinetic energy, capable of transmuting itself into heat, so gravity must be in essence also a kinetic energy capable of similar transformation. On this "hypothesis" all the consequences so incongruous with experience, as above indicated, would result. The ascending stone *would* have its energy "transformed into attraction," and the latter *would* be correspondingly increased. It would then be *truly* "said to consume the motion" of the stone. And when the stone was falling there *would* be "a certain amount of the attractive force converted into motion, and so the attractive force should be so far reduced." The reasoning is undoubtedly correct. "But instead of this, it is actually increased. There is therefore, [by the kinetic hypothesis,] no account given of what becomes of the motion externally imparted to the stone when thrown upward." And the undisputed facts of observation therefore, show us that if the kinetic hypothesis "be correct, then there *is* a destruction of force in the one case and a creation of force in the other." The conclusion is incontrovertible.

Seeing then the incongruity and inadmissibility of the assumed hypothesis, let us try a new departure. Let us, recurring to that only safe guide experience, recall as the necessary outcome of the fourth, fifth, and sixth propositions, that "gravitation is a property immutable and inconvertible." Let us, to avoid confusion of idea by the unconscious *double entendre* of the word "force," limit the term for the present to that innate and primitive tendency or tension which appears as the last result of dynamic analysis, and which obviously differs as much from the action of the falling stone, as the flying arrow differs in function from the *elasticity* of the bow which has impelled it. We shall thus have a term comparable in derivation and use to the "element" or the "atom" of the chemist, designating simply that which as a matter of fact, has not yet been further resolved. If now we deny (for the present purpose) the application of this term "force," to the dynamic action of the falling stone, and call the latter "energy," a term which conversely we deny to the primitive *vis motrix*, all confusion and inconsistency will disappear. Obviously, "conservation" can be intelligently applicable only to that which is capable of expenditure, transformation, or dissipation; as to matter, or to energy. To speak of the conservation of immutable gravitation is as unmeaning as to speak of the conservation of the equally immutable molecular *cohesion* or atomic *elasticity*. As a fact of daily observation, motion is a variable function, and like heat, color, form, or density, is not conserved.

When a stone is thrown upward therefore, it loses tension, because this *has been found empirically* to be the inflexible law of distance-ratio for the gravitative force, *and for no other human reason.* It gains in potential energy by the ascent, because there has been a corresponding expenditure of kinetic energy in *effecting* the ascent; and all experimental research proves the absolute constancy of the sum of these two forms of energy. And this constancy is all that is signified by the oft-quoted but not always justly apprehended "conservation of force." So far from there being any fixed relation between gravitative force and the conversion of motion, the ratio varies in every planet; and while the height to which a pound of gunpowder would project a ball upward would differ widely in different planets, the velocity of projection and the returning energy of the fall would be precisely the same in all. Were we to rigorously deny that gravitation is energy, or that energy is force, we could not correctly affirm the conservation of "force." The thing truly conserved would be energy, and this is undoubtedly the more accurate and less misleading form of expression.

Mr. Croll says in concluding his essay: "In the case of the loaded piston rising under the pressure of the steam, we have the pressure of the steam and length of space both diminishing as the *vis viva* or mechanical work increases. This is in harmony with the principle of conservation, for pressure or force diminishes as energy or work increases. But in the case of gravitation matters are reversed, for the force increases along with the work. As the weight descends and performs work, the pressure of the weight, the thing which performs the work, increases also; and when the weight is rising and energy diminishing, the force or pressure of the weight is not increasing but actually diminishing also." A very sufficient demonstration that steam and gravity are not correlated; that they are not both "forces" in the same sense of the term. Similarly a bar-magnet employed in educing magnetism in another steel bar, so far from losing what the other gains, has its own magnetism re-enforced by the operation. *Vires acquirit eundo.*

"This difficulty," says Mr. Croll, "along with all the others which we have been considering, will entirely vanish if we adopt the view of gravity which has been ably advocated by Faraday, Waterston, and other physicists, viz, that it is a force pervading space external to bodies, and that on their mutual approach this force is not increased, as is generally supposed; the bodies merely pass into a place where the force exists with greater intensity; for in such a case, the intensity of the force in the space external to any body is inversely as the square of the distance from the center of convergence of these lines of force. As the stone recedes from the earth its *vis viva* is transferred to space, and exists there as gravity. When the stone approaches to the earth, the force existing in space is transferred back to the body, and appears again as *vis viva*."*

Here then is an hypothesis which based on an *a priori* sentiment of fitness rather than on any direct induction, can be submitted to the test of observation. As a fact of observation, gravitation is always found to be a property of gross tangible matter, with its tensions mathematically directed to the mass-centers, and in quantity always directly proportioned to the number of material molecules, agreeably to the first and second propositions. As a fact of observation, the moon may pass

* Phil. Mag., *loco citat.*, pp. 456, 457.

through the very center of the space occupied by our earth only two weeks previously without any perturbation or consciousness of increased tension in this mystic "space." To affirm that the projected stone transfers its *vis viva* to space without suggesting any conceivable method by which such transfer could physically be effected, is not to proffer an hypothesis. To affirm that the falling stone receives from the illimitable ocean of space its just supply of *vis viva*—whether required at the instant or ten years afterward—is to bid us hope that the steam exhausted from the cylinder into the atmosphere may be induced to return to its duty when needed, in order to justify our faith in its conservation.

Nine years later, in a communication read before the British Association at Glasgow, September, 1876, "On the Transformation of Gravity," Mr. Croll repeats very much the line of argument just referred to, showing that the interval had not served to remove his difficulties. He commences his memoir with the query: "Is gravity convertible into other forms of energy? Can gravity be converted into heat, electricity, magnetism, etc.? or can those forms of energy be converted into gravity?" It might be supposed that the question would as soon occur to the physicist, Can the flight of the arrow be converted into elastic tension? The answer to his inquiry is directly involved in the fifth and sixth propositions. Mr. Croll, however, gives a different answer. "It may be true that gravity cannot be directly transformed into heat, electricity, magnetism, chemical affinity, etc., nor these forms directly transformed into gravity; but nevertheless, the thing may be done indirectly. . . . If the electricity produced by the descent of the water be gravity transformed into electricity, then the ascent of the water produced by electricity must be electricity transformed into gravity; for it is the same process merely reversed."* The alternatives are doubtless equally correct.

"If gravity be correlated to other forms of energy, it must like them come under the great principle of conservation. But here we enter upon debatable ground. It is admitted that gravity can perform mechanical work, and the mechanical work can be converted into other forms of energy. Here we have correlations; but it is generally denied that there is a decrease or loss of gravity resulting from such transformations. But this appears to me to be a virtual denial of the principle of conservation. . . . The reasons which appear to have led to this opinion are I think, mainly the two following: 1. It has been assumed [!] that the weight of a body is not affected by the work which it performs. 2. The force by which bodies are drawn toward each other does not diminish as they approach, but on the contrary increases. . . . May not a stone when in the act of falling be acted upon by gravity with less force at any given moment than it would be were the stone at rest at that instant? The point has never yet been determined

* Phil. Mag., October, 1876, vol. ii, pp. 241, 242.

either by experiment or by observation."* There is no conceivable reason why the falling stone should *not* "be acted upon by gravity with less force" than if it were at rest, (or why our fifth and sixth propositions should be true,) excepting the cogency of ascertained fact. Natural philosophy is an *experimental* science; and this point *has* been determined both "by experiment and by observation." The sensitive galvanometer needle of Faraday would have betrayed a *sigh* of commuting energy in the falling weight employed, while the actual increments of *vis viva* were really so large that they would have been a notable duty for the coarsest scales. And the ceaseless fall of planets from the tangents of their orbits, without any reduction of their own centripetal tensions, or of their satellitic control, is a constant and conclusive observation to show that this law or condition of gravitation—embraced in our sixth proposition—has not (as above suggested) been "assumed."

Mr. Croll continues: "But if the force of gravity does not sustain any loss as work is performed by it, what then is it that is supposed to sustain the loss? Some form of energy must diminish as work is performed; and if it be not gravity it must be something else. The generally received explanation is this: when a body is projected upward, the potential form of energy into which the upward motion of the body is transformed does not consist in the simple force of gravity or tendency of the body to descend, but consists in this force or tendency multiplied by the distance through which it is capable of descending. . . . This mode of viewing the matter, it is perfectly true, com pletely meets the mathematical and mechanical conditions of the problem; but for this very reason it seems to me to hide somewhat the real physical nature of the process. [!] . . . Space and time are conditions, but conditions absolutely necessary to the transformation of potential energy into kinetic, and of kinetic energy into potential; but they themselves cannot be forms of energy. But if it be true that the mere force of gravity or tendency of the stone to fall to the ground is not the potential energy, but that this potential energy is the force multiplied by the space through which it can act, then space must become a form of potential energy. This is evident; for the potential energy in this case consists of two factors, one of which is the *space* through which the force acts. It thus becomes just as much a form of energy as the other factor, viz, the force."†

The conclusion that space is "a form of" action, because all action is necessarily conditioned by space, does not appear so "evident." Mr. Croll correctly states: "But it is not in reference to gravity alone that this space-condition is essential to the transformation of potential into kinetic energy. It is as we shall shortly see, a condition absolutely necessary to the transformation of energy under every possible form. In the unbending of a spring the amount of work which can be per-

* *Loco citat.*, pp. 242–244.

† *Loco citat.*, pp. 244, 245.

formed is proportionate to the pressure of the spring multiplied by the space through which the pressure can act. The potential element, which in this case decreases as work is performed, is the tension or elastic force of the spring. Space is necessary simply to allow this tension to expend itself in work. It is this tension, not space, which reappears as work or kinetic energy."* In the case of a sling with a perfectly elastic cord whose elongation is proportional to the strain, the tension or potential element does *not* "decrease as work is performed;" on the contrary, it *increases* directly with the work; and whatever the centrifugal velocity of the ball, the period of revolution remains constant.† The elasticity does *not* "expend itself in work." *Vires acquirit eundo.* As this is simply the "*law* of force" for this particular tension, it has no relation whatever to "conservation," which pertains entirely to "work."

Again comparing gravitation to steam, whose pressure is weakened by the absorption of molecular motion in the rising piston, the writer repeats his questionings, "May not the same be equally true of gravity? In fact, *if* gravity has a dynamical origin, it must hold equally true of gravity and of heat." Again recurring to Mr. Waterston's conception that "gravitation is a function of space," he would almost lead us to forget that "space cannot be a form of energy." Again endeavoring to fortify his assumptions by scholastic dogmas, he reiterates, "the conception of attraction does not represent the *modus operandi* of gravitation, because attraction implies action at a distance, or in other words, that a thing acts *where* it is not, which is just as impossible as that a thing can act *when* it is not." Again affirming that "there is no necessity for forming any conception of the cause of which it is the effect," his whole dissertation appears impelled by the necessity to "represent the *modus operandi* of gravitation."

The general conclusion arrived at by Mr. Croll appears to be: "Gravity in all probability is of the nature of an impact or a pressure. Some of our most eminent physicists state that the force of gravity must either result from impact of ultramundane corpuscles, in some respects analogous to that of the particles of a gas, (which has been found to be capable of accounting for gaseous pressure,) or it must result from difference of pressure in a substance continuously filling space, except where matter displaces it. That gravity is a force of the nature of pressure is I think beyond all doubt; but that this pressure results from the impact of corpuscles, or from difference of pressure in a substance filling space, is purely hypothetical. Why not assume it to be a force, without calling in the aid of corpuscles or a medium filling space?"‡

If gravity be an abstract force, not requiring "the aid of corpuscles or

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*Phil. Mag., 1876, vol. ii, p. 247.

†The same isochronism exists with the revolving or conical pendulum whose vertical height is constant, or with one whose ball revolves in the surface of a paraboloid.

‡*Loco citat.*, p. 252.

a medium," it is not easy to perceive why it should so indubitably be "of the nature of *pressure*" rather than of *tension*. Is the phenomenon of the terrestrial tidal wave rendered any more intelligible by referring it to the action of a "pressure" from beneath, than by referring it, as the "most eminent physicists" do, to the action of a lunar tension from above?

Rejecting a pressure-medium as "purely hypothetical," the author yet thinks a pressure-force in gravity "is beyond all doubt"! not perceiving that the latter conception is as "purely hypothetical" as the former. A speculation born of metaphysical imaginings as to the "possible," framed in no physical relations to associate it with any known action, supported by no fact of observation, result of experiment, or sound induction, based on assumptions directly at variance with all ascertained laws or conditions of gravitative action,—if *such* a speculation be not "purely hypothetical," in what propulsive undulations, corpuscular chaos, or ætherial vortex, shall we seek to find a fitting subject for the appellation? And yet hypothetical as the speculation pre-eminently and undoubtedly is,—baseless, formless, insubstantial,—it comes to us with the *prestige* of a distinguished physicist as its propounder, and of a learned association as its audience and recipient.

Leray. 1869.

Within the last twenty years, probably more than a dozen "original" discoveries of the cause of gravitation have been announced to the French Academy of Sciences. Two brief essays of the same year may here be noticed. A Note by P. Leray, entitled a "New Theory of Gravitation," was presented to the Academy through M. Faye September 6, 1869.

"This new theory rests on the assumption of an æther—a fluid exceedingly rare and perfectly elastic—and on the two following principles: First, that in the free æther (that is, undisturbed by the presence of other bodies) there exist at every point equal currents crossing each other in all directions; second, that in passing through bodies, the currents of the æther are retarded proportionally to the thickness traversed, and to the mean density of the path. It may be added, that the currents thus enfeebled, on passing again into the æther, recover but slowly their former force, and may be considered approximately—within the limits of our solar system—as preserving a constant value." This gravific fluid evidently does not differ essentially from that of Lesage. These simple hypotheses, says the writer, "conduct in effect to the same results as the law of universal attraction, without requiring any action at a distance; and give moreover the key to many phenomena which this law does not explain."

Considering first, the case of an isolated body, it is evident that the currents, being equal in all directions, neutralize each other, effecting therefore no change of position in the isolated body; although by the *vis viva* absorbed from the æther, heat light and magnetism are produced in the body as shown in the stars. "This cause being permanent, explains without difficulty why the light and heat of the sun are constant"! A body in motion is of course retarded by the relative differential of the currents, although this retardation would be sensible only with very light bodies.

Considering secondly, the case of two bodies, (exterior to each other,) the currents enfeebled by traversing the bodies would impinge less strongly on the mutually-facing sides of the two bodies than on their exterior sides, thus producing an approach by the difference of impulse. And lastly, in regard to weight, this is the result of the quantity of motion communicated to a body by the shocks of the ætherial atoms. The two facts of experience, that the weight of a body remains invariable whatever its position, and that all bodies fall with the same velocity in a vacuum, prove that ponderable atoms are spherical, having an equal superficial density in all directions, and that all ponderable atoms are alike, or that there is ultimately but a single elementary substance.*

BOISBAUDRAN. 1869.

Another short paper, entitled a "Note on the Theory of Weight," was presented to the Academy September 20, 1869, by M. Lecoq de Boisbaudran, called forth by the previous communication of M. Leray. He remarks: "Having been myself occupied on this question, I have the honor to communicate to the Academy the actual state of my researches. On certain points, and particularly on the explanation of the central heat of the stars, I am happy to agree with M. Leray; on other points my conclusions differ from his. I attribute to matter, whatever may be its state of division, no other essential properties than those established by experimental physics and mechanics. I designate as atoms the last stage of division of matter. I admit that two bodies separated by an absolute void cannot act on each other; that action takes place only by contact, the play of forces following the laws of ordinary mechanics. If there existed but a single kind of atoms, the interchange of forces occurring between equal masses, two atoms could not unite. Force and matter would exist, but not attraction. There are then at least two kinds of primordial atoms of different masses. The smaller may be called æther; the others, ponderable atoms." The writer then goes on to say that a ponderable atom in the midst of a vibrating æther would itself receive a vibration (though of less activity than that of the æther) without being displaced in space, the portion of energy lost by the æther being transformed into heat, etc. A second atom being placed near the first, the æther vibrations would be feebler between the two than in exterior space, which would result in approach.

"I prefer the notion of vibrations of the æther to that of 'equal currents crossing each other in all directions.' The attraction exerted on

* *Comptes Rendus*, 6th September, 1869, vol. lxix, pp. 616–620.

a ponderable atom is not in the simple ratio of its mass; for if this mass equalled that of an æther atom, the attraction would be *nil*. If there exist ponderable atoms of different masses their rate of fall would be uneqal. If there were but one kind of ponderable atom, all bodies would fall with equal velocity. Experience seems to justify the last hypothesis; but *very slight* differences of mass in the ponderable atoms would suffice to determine the formation of chemical elements of very different atomic weights, and an inequality of their fall would escape unadvised observers."

After affirming the law of distance, M. Boisbaudran says: "In consequence of the inertia of the æther, attraction is not proportional to the real masses, but no more is it to the number of ponderable atoms contained in a body. The *vis viva* of the atoms of æther, however great, has a finite value." Lastly, he remarks: "It is to the longitudinal vibrations of the æther that I attribute the cause of weight."*

Neither the hypothesis of M. Leray, nor that of M. Boisbaudran, presents any feature of special novelty, requiring comment.

GUTHRIE. 1870.

In 1870, Prof. Frederick Guthrie published an account of some interesting experiments "On Approach caused by Vibration," unaware at the time of the earlier labors of Dr. Guyot in the same direction. He found that a card suspended near a vibrating tuning-fork was urged toward the fork, and by varying the experiment with smoke, with cork, with calcined magnesia, with floss cotton, with a second suspended tuning-fork, with brass disks, etc., he obtained similar results. At the termination of his experiments he thus sums up: "The experimental results appear to me to point to the following conclusions: whenever an elastic medium is between two vibrating bodies, or between a vibrating body and one at rest, and when the vibrations are dispersed in consequence of their impact on one or both of the bodies, the bodies will be urged together. The dispersion of a vibration produces a similar effect to that produced by the dispersion of the air-current in Clément's experiment; and, like the latter, the effect is due to the pressure exerted by the medium, which is in a state of higher tension [or pressure] on the side of the body furthest from the origin of vibration than on the side toward it. In mechanics—in nature—there is no such thing as a pulling force. Though the term attraction may have been occasionally used in the above to denote the tendency of bodies to approach, the line of conclusions here indicated tends to argue that there is no such thing as attraction in the sense of a pulling force, and that two utterly isolated bodies cannot influence one another. If the ætherial vibrations which are supposed to constitute radiant heat resemble the ærial vibrations which constitute sound, the heat which all bodies pos-

* *Comptes Rendus*, 20th September, 1869, vol. lxix, pp. 703, 704.

sess, and which they are all supposed to radiate in exchange, will cause all bodies to be urged toward one another."*

This hypothesis would make gravitation, or molecular attraction, a function of temperature, contrary to all observation; and is indeed entirely incompatible with the fourth, fifth, and sixth conditions of gravitative action. In short these experiments, striking and instructive as they unquestionably are, will be found on careful scrutiny to really simulate the effects of gravity in no one particular.

CROOKES. 1873.

From some very ingenious and interesting experiments made by William Crookes, in 1873, with light disks attached to a delicate torsion-balance and hermetically sealed within a nearly perfect vacuum, in which experiments the radiation of heat was observed to exert a repulsive effect upon the blackened side of the disks, he inferred that a clue was thereby probably furnished to the mystery of gravitation. He thus concludes his first memoir: "It is not unlikely that in the experiments here recorded may be found the key of some as yet unsolved problems in celestial mechanics. In the sun's radiation passing through the quasi-vacuum of space we have the radial repulsive force, possessing successive propagation, required to account for the changes of form in the lighter matter of comets and nebulæ; . . . . but until we measure the force more exactly, we shall be unable to say how much influence it may have in keeping the heavenly bodies at their respective distances. So far as repulsion is concerned, we may argue from small things to great, from pieces of pith up to heavenly bodies. . . . . Although the force of which I have spoken is clearly not gravity solely, as we know it, it is attraction developed from chemical activity, and connecting that greatest and most mysterious of all natural forces, action at a distance, with the more intelligible acts of matter. In the radiant molecular energy of solar masses may at last be found that 'agent acting constantly according to certain laws,'† which Newton held to be the cause of gravity."‡

Similar expositions are announced in Mr. Crookes' Journal for 1875, § and various modifications of the apparatus employed in the experiments are detailed. These little instruments, inclosed within an exhausted bulbous tube of glass, and with the disk-arms mounted on a pivot to permit continuous rotation, have since become quite familiar under the name of "radiometers," and have received a careful investigation from a number of observers. It is now known that they do not act by any impulsion of radiation, but solely by the differences of heat-absorption by

* L. E. D. Phil. Mag., November, 1870, vol. xl, p. 354.

† Referring, of course, to the "Third Bentley Letter."

‡ Philosoph. Trans. Roy. Soc., 1874, vol. clxiv, p. 527.

§ Quarterly Journal of Science, July, 1875, vol. v, p. 351.

the two sides of the disks and the reactions of the residual air of the exhausted chamber.*

In a later essay on "The Mechanical Action of Light," Mr. Crookes estimates that "the pressure of sunshine" amounts "to 2 cwts. per acre, 57 tons per square mile, or nearly three thousand million tons on the exposed surface of the globe;—sufficient to knock the earth out of its orbit if it came upon it suddenly.† It may be said that a force like this must alter our ordinary ideas of gravitation; but it must be remembered that we only know the force of gravity between bodies such as they actually exist, and we do not know what this force would be if the temperatures of the gravitating masses were to undergo a change. If the sun is gradually cooling, possibly its attractive force is increasing, but the rate will be so slow that it will probably not be detected by our present means of research."‡

This possibility is denied by our sixth proposition. The generalizations embraced in our first, second, and third propositions are assumed to be equally true at all possible temperatures; and the ground for this assumption is, that they have been actually ascertained to be true for all observed variations of temperature. The induction can therefore be arraigned only by a conflicting fact of observation or experiment. Varied and delicate experiments have actually been repeatedly made from the time of Fresnel to the present, to detect if possible an influence of heat on weight, but without result. Indications sometimes observed have always been found to be due either to currents in the best approximate vacuums or to the molecular reactions from unequal absorption. It is evident that if heat radiation could exercise the slightest influence upon gravitative attraction, it would be possible in many cases to interpose a screen to its action, contrary to the observed fact generalized in our fifth proposition.

We are correctly reminded that "we only know the force of gravity as between bodies such as they actually exist;" but this knowledge teaches us that the ratio $\frac{m}{r^2}$ is invariable; that therefore the exponent 2 of the radius or distance is integral, and is not a residual of an exponent $2+n$. Finally, we know that heat radiations require eight minutes to pass from the sun to the earth. The inferences then that the conduct of the "radiometer" affords any key to the problem of celestial mechanics, or that it illustrates or suggests any analogous "agent acting constantly according to certain laws" as "the cause of gravity," are evidently unfounded and erroneous. "Nor must we forget that the more rigidly we scrutinize our received theories, our routine explanations and interpretation of nature, and the more frankly we admit their shortcomings, the greater will be our ultimate reward."§

* This view has since been accepted by Mr. Crookes himself.

† If any such action really existed, its effects would be just as certain and as disastrous if applied gradually as if applied suddenly.

‡ Quarterly Journal of Science, April, 1876, vol. vi, p. 254.

§ *Loco citat.*, p. 256.

In this résumé of kinetic theories, doubtless other names, well deserving notice, have been overlooked from want of more extended research; but it is believed that the foregoing survey comprises essentially all the forms of the hypothesis of primeval motion which have been propounded. The general tenor of this line of speculation has been well set forth in an able review of "The Atomic Theory of Lucretius," which appeared in the North British Review for 1868.

"The most plausible suggestion yet made by this school is that a single omnipresent fluid æther fills the universe; that by various motions of the nature of eddies, the qualities of cohesion, elasticity, hardness, weight, mass, or other universal properties of matter are given to small portions of the fluid which constitute the chemical atoms; that these, by modifications in their combination, form, and motion, produce all the accidental phenomena of gross matter; that the primary fluid by other motions, transmits light, radiant heat, magnetism, and gravitation; that in certain ways, the portions of the fluid transmuted into gross matter can be acted upon by the primary fluid which remains imponderable or very light, but that these ways differ very much from those in which one part of gross matter acts upon another; that the transmutation of the primary fluid into gross matter, or of gross matter into primary fluid, is a creative action wholly denied to us; the sum of each remaining constant."* The hypothesis of the transmutation of æther, or of the evolution of "matter," is not however necessarily involved in that of referring all conditions, properties, and powers of matter to "a mode of motion."

General Conclusions.

In the conception of a *statical* pressure of æther constantly acting inwardly on concentric spherical surfaces, there is the obvious irrationality of a stable non-equilibrium. Nor is there any real difference in the conception of an æther having concentric increments of density outward, in which ordinary matter is buoyed, as it were, toward the center: a scheme in which every particle of matter finds itself in the midst of its own little spheres of rarefaction, and in which such center of ætherial rarity is supposed to blindly follow the flying stone in whatever direction hurled at the caprice of an idle boy. Entirely too much importance has been attached to this conception as a speculation of Newton, when it was evidently an unconsidered and merely *obiter dictum* suggestion, utterly repudiated by him in later years.

Omitting then any further consideration of the *statical* method of explaining gravitation by pressure, we find that *kinetic* systems are essentially of two classes, the hypotheses of emissions or corpuscles, and the hypotheses of fluid undulations. It is proposed to show that no form of either hypothesis can satisfy the two Newtonian conditions of a scientific theory—*verity* and *sufficiency*.

*North British Review, March, 1868, vol. xlviii, p. 127 of Am. edition.

The corpuscular hypothesis is clearly invented *pro hac vice.* Nor can even an analogue of the invention be found in the corpuscular theory of gases; for in the latter case, the free path of the particle is assumed to extend only for the short distance between neighboring molecules, and by reason of incessant collision and deflection among the elements the hydro-dynamic pressure of the medium is equal in all directions, quite irrespective of the number or character of intervening obstructions: while the gravific or ultramundane corpuscle must *ex hypothesi* travel from infinity in a perfectly straight and undisturbed path to fulfill its appointed mission. It is therefore a special creation, neither ascertained nor suggested by any other consideration.

Secondly, even if a *vera causa,* it is wholly insufficient. The first great triumph of the corpuscular assumption was its supposed happy expression of the distance-ratio of gravitative intensity: and this appears to have been admitted by all the mathematicians who have referred to the problem. But a very brief consideration will show that while this may be approximately true for small masses, there is a limit of magnitude as well as of number in the masses of gross matter, beyond which no *assignable* number of corpuscles is capable of acting. Let us suppose for definiteness (not as even suggesting a higher limit) that normal to a plane whose area is d^2, (d representing the distance between two adjacent molecules of ice or of water,) a million million corpuscles are passing *simultaneously* with any desired frequency. This neglects for the moment the far greater number passing through the same area at all other angles. The molecule of ice or water being a very small though appreciable fraction of the value of d, (a not improbable estimate of which value may be the five hundred millionth of an inch,) it is obvious that with an equable distribution of the material molecules in a continued right prism having d^2 for its base, no very great depth is required for a million million of such molecules to lie each in the line of motion of one of the parallel moving corpuscles. Beyond this depth or distance, of any number of molecules continued, no one will receive an impact, or in other words, will have any gravitation.* This reasoning remains true, whatever be the number and direction of the prisms chosen, and whatever be the number of corpuscles passing through its base d^2. If it be said that this number is infinite, this is simply an unconditional surrender of the hypothesis. It is proved then that the number of corpuscles passing through a *large* mass must be very much less than the number impinging on its exposed strata or passing through a small mass; and that if the mass be *large enough,* the side presented toward another mass will receive no gravitative impulse thereto; and a tidal

* This idea may be more popularly illustrated by supposing on a plane of indefinite extent a grove of small, vertical trees, planted at irregular but equable intervals, at *any assignable distance apart.* It is evident that it would require no indefinite extension of the woods to absolutely exclude a horizontal ray of light in any direction, even though suns or electric lights were blazing with unimaginable splendor.

attraction between the bodies would be impossible! The scheme therefore fails not only to satisfy the second condition, (as formerly stated,) but it equally fails to satisfy "indefinitely" the *third* condition. And this objection lies equally against every variety of the corpuscular hypothesis, from that of Bernouilli to that of Leray.

In the next place, the hypothesis of undulations similarly fails. First, because the motion assumed is not a *vera causa*. If it be answered that an all-pervading æther and its system of undulations are otherwise established, by the large array of well-observed phenomena shown to be in exact accordance both in quantity and in quality with the mathematical deductions from such postulated undulations, the rejoinder is, that such undulations as have thus been established are demonstrably incapable of inducing anything in the slightest degree analogous to gravitation; and therefore the *new* undulations required have *not* been otherwise ascertained. And this is a radical defect in all the wave suppositions. We are not at liberty to assume unknown and undemonstrated actions, entirely different in character from anything which has been actually observed or necessarily inferred. Great as is the credit due to Professor Challis, for instance, for his dexterous, persevering, and laborious efforts to develop his theory by the stern logic of mathematics, the whole demonstration is vitiated by the unwarranted prelimnary assumption of qualities and modes of action in the æther analogous to those of gases; as for example, that the pressure and the density are proportional. Now as a matter of fact, the æther is a medium so wholly and so radically dissimilar to any known gas in structure and in properties, that the most characteristic features of its luminiferous undulations,—rectilinear propagation, with its special incident inflection; selective refraction or chromatic aberration; birefraction; and polarization in its various forms,—find no representative therein; leading a Newton to the reluctant conviction that a *gaseous* æther could not be the vehicle of light.* The denial therefore, of the *verity* of fluent undulations in the æther is based upon the skeptical affirmation that beyond experience and safe induction therefrom, we can tell nothing as to the behavior of an unknown agent.

But if the character of undulation required were established, secondly, it would as in the former case, be entirely insufficient for the purpose. The æther must have the elasticity and the mass or inertia

* Dr. Young, in referring to Fresnel's discussion of "polarization," says, "it might be inferred that the luminiferous æther pervading all space, and penetrating almost all substances, is not only highly elastic but absolutely *solid.*" (Miscellaneous Works of Thomas Young, London, 3 vols. 8vo, vol. i, No. 18, p. 415.) And Sir John Herschel remarks: "Every phenomenon of light points strongly to the conception of a solid rather than a fluid constitution of the luminiferous æther, in this sense,—that none of its elementary molecules are to be supposed capable of interchanging places, or of bodily transfer to any measurable distance from their own special and assigned localities in the universe." (Familiar Lectures on Scientific Subjects, London, 1867, lect. vii, p. 285.) On the other hand, recent mathematical discussions have found some difficulties even in this hypothesis.

necessary to execute precisely its ascertained dynamic function.* This specific and very limited inertia is manifestly inadequate to the indefinite accumulation of energy required to give the same proportional tendency between large masses as between small ones. The experiments of Guyot and of Guthrie quite conclusively show that neither in the law of quantity nor in the law of intensity can gaseous vibrations represent even approximately the ascertained facts of gravitation embodied in the second and third propositions.

But if in dynamic action a gaseous undulation of æther, with its existing co-efficient of inertia, is found to be so palpably inadequate to the known effect, on the other hand the *elasticity* must be assumed to be incomparably more active than the limit expressed by the actual velocity of a luminous undulation. If its rate of propagation be assumed to be very many millions of times more rapid than that of light, the inertia must be correspondingly reduced; in short, must be practically *nil;* and the action must be really kinematic rather than dynamic.

Failing thus at every point, the hypothesis leaves still more inscrutable the *origin* of the undulation. The center of disturbance is supposed to be the vibrating material element; but the cause of the vibration is never stated. If *innate tendency* be the answer, never surely was a more mysterious "occult quality" attributed to matter in the history of human excogitations. Either misapprehending altogether, or quite ignoring the origin of thermal vibrations, the kinetic theorist not unfrequently appeals to the dynamical doctrine of heat as the type and the warrant of his assumptions. But in the case of heat, as in every other observed case, *motion* is a phenomenon to be accounted for; and no physical theory is complete, until in origin, in quantity, and in direction, it is accurately explained by a true and sufficient antecedent cause.

But granting a prime mover—the immediate operation of a Demiurgus, if necessary,—how is the initial impulse converted into vibration? What is the resisting power deflecting the element in motion from that rectilinear direction, which is its first law of action? And by what *opposing* battledoors (for *two* are absolutely necessary) does the deflected particle become a shuttlecock? Upon these important questions there is a very remarkable reticence. We know that when a bell is struck with a hammer the moving impulse of a segment of the free edge is resisted by a molecular pressure which (for want of a better name) has been called *repulsion;* and that this reaction is in turn resisted by a molecular tension which (for want of a better name) has been called *attraction;* and that this reciprocating play very rapidly declines as

* From the actual dynamic energy transmitted by the æther, Sir William Thomson, in 1855, estimated that a cubic foot should weigh not less than the quadrillionth ($1 \div 10^{24}$) of a grain; or that the inertia of æther had for its higher limit about one two-thousand-trillionth ($\frac{1}{2} \div 10^{21}$) of that of ordinary air. (L. E. D. Phil. Mag., January, 1855, vol. ix, p. 39.) Its *lower* limit may be one hundred times this amount, or one twenty-trillionth ($\frac{1}{2} \div 10^{19}$) of the inertia of air.

the momentum of vibration is transferred to the elastic air. And these two qualities of the vibrating bell—cohesion and elasticity—as Sir John Herschel has well remarked, "we have no means of analyzing further, and must therefore regard them, till we see reasons to the contrary, as *ultimate phenomena*, and referable to the direct action of an attractive and a repulsive *force*."* But in a kinetic system there is no room for such abstractions. How then are they to be displaced and superseded? We wait in vain for an intelligent or an intelligible answer.

But after this long list of difficulties, supposing the vibrating particles set in motion, still by the Demiurgus, with his right and left propulsions, by what power (short of his incessant repercussion) is the vibrating particle enabled to transmit without decline or interruption, these ætherial waves of gravitation—let us say for a single year, we might as well have said for a single minute? Here again we listen vainly for an answer!

And thus, step by step, have we been led to the culminating vice of *every* kinetic sytem; its utterly reckless violation of any rational conception of the conservation of energy. And yet remarkably enough, the ostensible impulse and occasion of such creeds have usually been a strong veneration for this much-abused principle, and the consciousness of a special mission to restore and to vindicate its neglected authority! Not unfrequently the vibrations communicated to the telegraphic æther by a trembling atom have been supposed to be transmitted unimpaired to that or to other atoms, and back again, in endless and magnificent cycles of "perpetual motion." And as "there is no limit to the *vis viva* which such a medium may conserve" within its boundless bosom, such projectors have the Bank of the Infinite on which to draw in every dynamic emergency, without the fear of a depleted treasury, and without any necessity being felt for inquiring too nicely into the balance of the depositor's account. And thus, as Leray has intimated, suns and stars are maintained for ever blazing on a borrowed capital of motion.

In opposition to all this ideal programme of an illimitable ocean of dynamic, with its treasures lying loose in space, to be absorbed by every projected ball or stone, it may be simply declared that from *observation* we have no reason whatever to believe the æther to be in any case a *source* of energy. We have absolutely no experience of any undulations originating in its broad expanse. It is never self-luminous; and even in the case of electricity there is always required the disturbance of a material element. Nor is there any ascertained fact to warrant the supposition that the æther is a *reservoir* of force,—in any other sense than that without the possession of intrinsic tension it would be incapable of *transmitting* energy. So far therefore as sober experience is accepted as our guide, we only know that a mechanical impulse of suitable character being committed to the æther, it is a faithful *vehicle* of energy, never adding to, and never abstracting from its charge.

* Prelim. Discourse on the Study of Natural Philosophy, part ii, chap. ii, sec. 80.

Among the names presented in the foregoing selection from kinetic theorists are several eminent in the domains of physics and mathematics. Their labors, animated with the zeal, the diligence, and the persistency of purpose and conviction here displayed, might be expected to enlarge notably the boundaries of our knowledge to whatever department of natural law they were devoted. But when we look for any actual results from these elaborated speculations, how barren is the prospect. How wonderfully contrasted in character is the prime assumption with the fruitfulness of that generalization which it aims to subordinate and to comprehend. How striking its failure, not in the higher *rôle* of prophecy, but in the humbler one of mere interpretation. How clumsy the mechanism by which it vainly strives to accomplish its results.

But it is not simply in the negative aspects of an unsuccessful effort that these varied speculations, prompted by a common sentiment and motive, teach us their most suggestive lesson. Beyond the facts of constant and of signal failure, these restless, resolute probings by the human mind in all directions, serve as the cumulative bases of a new induction; and by the very sharpness of the contrasts brought to view at every point between the tentative conjecture and the determinate experience, they enforce the assurance, that whatever else the principle of gravitation may be, it is not in its essence any form of *motion*. And that gravitation is not a resultant of *pressure*, appears to be very clearly made out by the inability of every scheme of such hypothesis, in the hands of its most skilfull adherents, to give any rational account of the semi-diurnal ocean-tides.

Another lesson no less striking, is the utter worthlessness of metaphysical axioms as a criterion of physical truth, or as a foundation for rational physical theory. Such propositions as "It is impossible to imagine an infinite attribute belonging to a finite entity," or "It is impossible to conceive anything to act where it is not," are not merely quite irrelevant to scientific verity, but if gravely accepted as physical postulates, prove only to be positive obstructions to scientific investigation. Professor Challis has well said, "I do not admit that any *metaphysical* argument can be adduced either in support of or against a physical hypothesis. *Meta*-physics come after physics." * And Sir John Herschel, some thirty years ago, laid down as a rule of sound philosophy, "Expepience once recognized as the fountain of all our knowledge of nature, it follows that in the study of nature and its laws we ought at once to make up our minds to dismiss as idle prejudices, or at least suspend as premature, any preconceived notion of what might or what ought to be the order of nature in any proposed case, and content ourselves with observing, as a plain matter of fact, what *is*." † And again, long before him, Newton condemned the "feigning hypothesis for explaining all things mechanically, and referring other causes to metaphysics. Where-

* L. E. D. Phil. Mag., 1861, vol. xxi, p. 505.

† Discourse on Study of Natural Philosophy, part ii, chap. i, sec. 68.

as the main business of natural philosophy is to argue from phenomena without feigning hypotheses, and to deduce causes from effects, till we come to the very first cause, which certainly is not mechanical." *

It has already been noticed that *elasticity* has proved a stumbling-block to every kinetic hypothesis. A system of molecular physics without this property would represent a chaos; but a chaos destitute of energy. As Lamé has well observed in his admirable treatise on the subject, "The *rôle* of Elasticity in nature is as important as that of Gravitation!" How then are we to formulate this prime and potent force? Evidently no phase or form of *motion* can simulate its action. Here all *kinetic* theory fails: and there is then something in the world beside "inertia and motion." Until some rational analysis be discovered, we must accept the fact (in the language of Sir John Herschel) as an "ultimate phenomenon." And as we find that the molecules of all material substance resist compression with a force proportional in some high ratio thereto, we can only conceive that they are separated by an interval through which this repellant resistance is exercised. Here then it seems, we are at once confronted with an "occult quality" or virtue, a force of *repulsion*, quite beyond the reach of any explanation or relegation. And worse than all, with a quality or virtue which proves to be that ever-dreaded and in fact "impossible" *actio in distans!* Are we then driven in the last resort to admit that devoid of all perception of propriety, the insignificant physical molecule does positively "act where it *is* not," and where it *ought* not?

When we endeavor to penetrate into the secrets of molecular physics, again are we borne on the waves of a large induction that the atoms of matter never are and never can be in contact: but that in Seguin's fine conception, they are really circulating in perpetual orbits of varying magnitude, according to the resultants of impulsions received by mutual impacts on their dynaspheres, or on the mystic boundaries of their elastic repulsions: in orbits whose magnitude determines the character of their aggregation, and which notwithstanding constant perturbation, could be suppressed only by the total absorption of motion, in an absolute zero of temperature. And thus, whether we contemplate the infinitely small or the infinitely grand, in every case comes back upon us the wide induction, that the action of matter in atom, in molecule, or in mass, is *ever* at a distance! Of actual *contact* there is probably no instance afforded in nature, excepting in the intimate substance of the ultimate atom. And notwithstanding the petulant sneer of some distinguished physicists, there is nothing to forbid (on the contrary much to favor) the Newtonian conception of infinitely hard spherules of determinate magnitude, as the real substratum of the physical universe.

The assumption therefore of a material band or bar between bodies, to transmit energy from one to another, whether by a pull or by a push, is

* Optics, Book iii, Query 28.

still very far from establishing an action *by contact*, or from sustaining the fond hypothesis that an atom "acts where it *is!*" Admitting a connecting rod for drawing the railway train of dynamic, as Professor Maxwell has remarked, "the action of the rod is explained by the existence of internal forces in its substance; and the internal forces are explained by means of forces assumed to act between the particles of which the rod is composed, that is between bodies at distances which, though small, must be finite. The observed action at a considerable distance is therefore explained by means of a great number of forces acting between bodies at very small distances, for which we are as little able to account as for the action at any distance, however great."*

To the wondering inquiry what possible explanation can be given of

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* A Treatise on Electricity and Magnetism: by James Clerk Maxwell. Oxford, 2 vols. 8vo, 1873. Part i, chap. v, sec. 105, vol. i, p. 123.

If the attempts hitherto made by kinetic theorists to explain the tensile strength of a rope or of a chain by the pressure of a *vis a tergo* have been exceedingly lame and unsatisfactory, even the more direct examples of actual impact and propulsion are really as little serviceable to the hypothesis of contact action. If we have good reason to believe that the constituent molecules of a steel bar are actually separated by relatively large spaces of intense repulsion,—*a fortiori* must the physical impact of the most violent percussion be resolved into an action through a vacant space. Taking the case of a steel ball struck suddenly by a steel bat, the interval of distance between the first impression of the moving mall and its nearest approach to the ball, is sufficient to permit the acceleration of motion in the missile through every gradation, from zero to its full velocity.

Perhaps no better "prerogative of instances" of a physical contact could be suggested than that of a thick glass plate resting on the convex surface of a large glass lens, since the perfectly-ground plane surface of the upper glass and the perfectly-ground spherical surface of the lower one are best adapted to exclude a possible film of air. Such an arrangement represents the well-known experiment by which Newton determined from the measurable variation of distance between the glasses (when closely pressed together) the wave-length of light for different colors. On this very beautiful experiment Dr. Robison forcibly remarks in his excellent work on Natural Philosophy:

"The conclusion seems unquestionable that we have no proof from the black spot between the glasses, that they are in mathematical contact in that place. We know by the first experiment that a very considerable force is necessary for producing the black spot. A greater pressure makes it broader, and in all probability this is partly by the mutual yielding of the glasses. I found that before a spot, whose surface is a square inch can be produced, a force exceeding one thousand pounds must be employed. When the experiment is made with thin glasses, they are often broken before any black spot is produced. . . . . There is therefore an essential difference between *mathematical* and *physical* contact; between the absolute annihilation of distance, and the actual pressure of adjoining bodies. We must grant that two pieces of glass are not in mathematical contact till they are exerting a mutual pressure not less than one thousand pounds per square inch. For we must not conclude that they are in contact till the black spot appears; and even then we dare not positively affirm it. My own decided opinion is, that the glasses not only are not in mathematical contact in the black spot, but that the distance between them is vastly greater than the eighty-nine-thousandth part of an inch, the difference of the distances at two successive rings."—A System of Mechanical Philosophy: by John Robison. 4 vols. 8 vo., Edinburgh, 1822, vol. i, sec. 241, 242, pp. 250, 251.

such a theory or hypothesis of attraction, the obvious answer is, there is neither "theory" nor "hypothesis" in the case. The observed fact that one body does actually induce approach in another body at a distance from it, if accepted as an "ultimate" one, is of course thereby excluded from all idea of "explanation." And as this observed fact, by the multiplicity of instances in which no intermediate agent has yet been detected, or rendered rationally plausible, is generalized into an "induction," the burden of proof lies entirely on the shoulders of those who with a keener vision through nature's veil, are ready to proffer hypotheses "without assumptions," and endless motions without the aid of "occult qualities."

But this stern requirement of a demonstrated instance of material link, or mechanical connection, to impugn the large induction of an *actio in distans*, cannot be evaded by the logical artifice of designating such "induction" as a competing "hypothesis!" If by the scientific method of a carefully registered experience such theorists should ever be successful in *physically* justifying their ill-advised scruples, their *mala fastidia*, (to use the phrase of Horace,) none will be more heartily rejoiced at this new conquest over ignorance than the astronomers and physicists who hitherto have given themselves but small concern respecting the metaphysical paradoxes supposed to be involved in the more usual statement of the law of gravitative action.

But as yet this generalization, after two centuries of busy thought and daring speculation, still remains the largest, clearest, surest, yet attained by man; and with each revolving year new demonstrations of its absolute precision and of its universal domination serve only to fill the mind with added wonder and with added confidence in the stability and the supremacy of the power in which has been found no variableness, neither shadow of turning, but which, the same yesterday, to-day, and forever,

"Lives through all life, extends through all extent,
Spreads undivided, operates—*unspent!*"

THE REVOLUTIONS OF THE CRUST OF THE EARTH.

By Prof. GEORGE PILAR, *of the University of Brussels.*

[Translated for the Smithsonian Institution by M. A. Henry]

CHAPTER I.

ORIGIN OF THE EARTH.

As far as the assisted eye can penetrate the depth of space, we find that attraction is one of the fundamental properties of matter. It is inherent in all bodies, whatever may be their form, whatever their nature. Its energy is in inverse proportion to the square of the distances, and proportional to the masses: its action is limited neither in time nor space.

If we examine attentively the universality of this force, its unlimited action, we must arrive at the conclusion that matter, of which attraction is only a property, is equally infinite in time and in space; that it exists everywhere, and is constantly transformed; its activity is a natural result of its properties, and we may say after careful study of all relative phenomena that matter without properties, and consequently without activity, cannot exist.

We have only to direct our thoughts to the innumerable worlds, whose history, written on the starry vault, has left much concerning them still unrevealed; to consider simple immensity and eternity and oppose to them the *where* and the *when* of the origin of matter; to endeavor to imagine what could have existed before or at the time of its appearance, and we will easily conceive that its essence is necessarily infinite, and that its activity, which is partially manifested in universal attraction, is permanent and eternal.

We may say then that matter fills space without limit, and that from its bosom constantly proceed worlds without number under the form of light vapors, which, grouped together by the effect of attraction, create nebulæ, which unceasingly increase in volume by the addition of matter of analogous formation. In these nebulæ are produced different centers of attraction, around which collects the still diffuse matter. As condensation advances, the heat disengaged increases in proportion, and whenever this exceeds radiation there is an accumulation of heat which produces incandescence of the entire gaseous mass.

Each of these centers of attraction forms the germ of a solar system, and each passes through the same phases in the course of its develop ment, differing only in the time occupied in going through these changes.

What are these phases, and what is the order of their succession?

The hypothesis of M. Faye in regard to the development of celestial bodies has the advantage of accounting for a large number of cosmical phenomena, and at the same time of giving an exact idea of the activity of matter, from its extreme dispersion, to the formation of planets. As it is founded upon the physical constitution of the sun, it may be well to give a glance at some of the theories which have been formed in regard to this luminary.

According to the Scotch scientist, Wilson, the sun is an opaque, solid or liquid body, surrounded with a dense atmosphere, the exterior strata of which are luminous in themselves and constitute the photosphere. Arago proved the existence of an incandescent gas, by means of the polariscopic telescope; for from the entire surface of the solar disk he obtained no polarized light, which would not have been the case if the sun were a solid body or an incandescent liquid. In order to explain the penumbra, W. Herschel supposed between the sun and the photosphere the existence of a cloudy envelope, which reflects and absorbs all the luminous and calorific rays. The production of spots was attributed to gaseous emanations of a volcanic nature, which rend the cloudy envelope and the photosphere and allow us to perceive the opaque body.

Moreover the appearance of the spots toward the edge of the sun, according to all the laws of perspective, indicate that they are actual depressions and not protuberances, as Leland considers them, nor a superficial phenomenon, as La Hire has supposed, nor yet clouds, as M. Kirchoff has declared them to be in an hypothesis generally accepted in Germany. As the latter hypothesis is connected with a discovery of great importance to spectral analysis, we will consider it more in detail.

It is evident from the investigations of Angstrom that gases and vapors always absorb the rays of refrangibility, corresponding to those they would themselves emit, if they were carried to incandescence. Starting with this fact, MM. Bunsen and Kirchhoff have shown that we may produce certain lines of the solar spectrum, by interposing vapors of different metals in the path of the light of a continuous spectrum, proceeding from an incandescent body. In order to apply to the sun the results of this experiment, M. Kirchhoff supposed the sun to be a solid or an incandescent liquid, surrounded with an atmosphere containing vapors of different metals of which we perceive the dark rays in the solar spectrum. The spots, according to this hypothesis, are only clouds of conical form, which are produced by a sudden cooling of certain regions of the solar atmosphere. The protuberances, having the appearance of floating clouds, which are observed during total eclipses of the sun, appear to confirm this view. But when we consider, what is well known, that the spots are seldom seen beyond 50° of latitude north and south, while the protuberances appear in all latitudes,* this particular proof loses its force.

Furthermore, Warren de la Rue has brought absolute proof to the support of the existence of a cavity in the spots. Two photographs of the sun, taken with an interval of two days between them, and united in a stereoscope, give clearly the perception of a cavity.

These considerations, and many others, cause us to prefer the hypothesis of Wilson, Herschel, and Arago, who admit the existence of a photosphere of a cloudy envelope, and an opaque interior.†

It remains for us to inquire what is the nature of this interior; is it solid, liquid, or gaseous? In what way does the sun produce the enormous amount of heat it has given forth from immeasurable time? And how are produced the spots whose origin has been explained in such different ways?

A close observation of the formation of the spots, and of the phenomena which precede and follow them, has furnished Mr. Faye with the elements of his hypothesis, in which he declares that the solar mass is entirely gaseous, because the ascending currents which produce the spots proceed from very great depths in the solar mass, and consequently that it is the contraction of this gaseous mass, which furnishes the enormous heat radiated into space.

The extension of the same phenomena to all the stars, and to all matter in course of formation, raises the value of this hypothesis which, however, does not claim to be perfect. It is in fact only a sketch, made by the hand of a master, which still requires some touches of the pencil to make it a complete picture, embracing in its generalities the cosmic life of matter. Let us consider the hypothesis more in detail.

There exist gaseous masses of a temperature superior to all chemical affinity. This great heat is produced by the contraction of the mass, and the disappearance of a considerable quantity of *vis viva;* but as the gases are bad conductors, and exist in a state of great division, the emission of heat and of light is very feeble, (nebulous type.)

There comes a time when by the progress of condensation, and by the cooling of the surface of the nebula, chemical forces come into action; there are then produced the liquid and solid particles which distinguish the exterior strata of the gaseous mass the photosphere. But as the solid and liquid particles are denser than the rest of the mass, they fall toward the center of gravity. There they are volatilized anew, under the influence of the high central temperature, and determine ascending currents of gas, which are in their turn cooled and feed thus the photosphere, which is more or less agitated, according to the intensity of the currents. (Type, *sun, star.*)

When the entire mass of a star becomes thickened to such a degree

* E. Plantamour, *Observation de l'éclipse totale de soleil du* 18 *juillet* 1860, *à Castellon de la Plana;* Guillemin, *Le Ciel.*

† See further details of these hypotheses Faye *Comptes rendus*, t. ix, 1865, p. 89–96.

by continued precipitations that the exchange of heat between the center and the periphery can no longer take place by means of currents, the luminous envelope disappears for want of aliment, and it is only after a sufficiently prolonged repose that the expansive force of the gas succeeds in overcoming the resistance, and envelopes the entire globe with a photosphere, which will be extinguished again when equilibrium is established between the expansive force of the gas and the pressure of the condensed matter. (Type, *variable star*, *temporary star*.)

These phenomena may be repeated at intervals more or less considerable, but the effects of the cooling is manifested more and more, until finally the luminous phenomena cease entirely. It is then the geological life of the star commences.

The sun is still far from the exhaustion of its calorific capacity, but it has only a shadow of its former greatness. It extended, before the formation of the planets, beyond the limits of our present system. The equivalent of heat lost since that time in the generation of the force necessary to divide the mass of the sun from the planets would make it occupy a space whose radius would extend beyond the orbit of Neptune. The attenuation of the solar matter must have been extreme when our system formed one continuous whole, with the mass of the other stars of the milky-way.

We have considered the formation of the great centers in a general way; let us now examine their particular development, which we can study only in our solar system.

We follow in this the theory of Laplace, suggested to the great geometrician by the discovery of the rings of Saturn, in which, to use his own expression, "man detected nature in the execution of one of her mysterious creations."

Our solar system had, before the creation of the planets, a form very much flattened, in consequence of its movement of rotation and of its gaseous nature. In fact, the centrifugal force and the expansive force, which both increase with the distance from the center, counterbalanced the attraction, and produced a considerable enlargement in the plane of the equator. When a certain portion of the nebula, on account of the equilibrium of these contrary forces, could no longer participate in the general movement of contraction, a ring was formed, which circulated around the central body with the velocity it had acquired as a portion of the generating body, when the dimensions of the latter were the same.

Several rings were detached thus, successively, and continued to condense independently of the central body, until, by an exterior influence, or by the preponderating attraction of nuclei formed within their substance, they broke into fragments of unequal volume. The principal nucleus, collected about a center of gravity the largest part of the mass, which had formed the ring, and was then in the same condition as the generating body, that is to say, that it could give birth to other bodies, still less important, viz, to satellites.

As to the movement of the secondary bodies, this was regulated by the rotation of the principal body. When the mass of the ring commenced to condense, two movements were produced, through its connection with the center of gravity of the solar system. The parts nearest to the sun were removed (by the condensation) farther away, that is, nearer to the planetary center, and as their velocity, on account of their inertia, remained the same, and as, besides, this velocity was less than that of the center of gravity of the planet, they had a tendency to fall behind. The parts farthest from the sun, on the contrary, approached nearer to it, and their angular velocity, being originally greater, they had a tendency to advance beyond the center of gravity of the planet. These two contrary motions made the secondary body turn around the principal body in the direction in which the latter revolved around the sun.

The ring which must have formed our earth was remarkable neither in position nor size; but as it is the only one of which we know, although very imperfectly, the different phases of planetary development, it must especially attract our attention.

We have already shown how every ring must finally break and conglomerate its substance into a single spheroid, in which are manifested the same luminous and calorific phenomena as in the sun, although with less intensity, as these must be in proportion to the mass. The earth, by the contraction of its gaseous globe, acquired a movement of rotation, increasing in rapidity as the volume became less. At the distance of sixty terrestrial radii a ring was detached which afterward gave birth to the moon. The globe diminished more and more in volume until the cooling became so considerable that the liquids formed in the photosphere were precipitated in the order of their density. A thick atmosphere enveloped this incandescent nucleus.

The increase in temperature of the earth toward its center, its density too slight, (5.44 according to Reich,) for the enormous pressure of its entire mass, the nature of the ancient eruptive rocks and the flattening of the globe prove that the earth has passed through a liquid and incandescent condition, and notwithstanding its present coolness, its central heat is still great. It is true that Herbert Spencer demonstrated * that it was not necessary for the earth to be in a soft state to be flattened. As the intensity of the centrifugal force increases in cubic proportion to the dimension of the mass, while under the same conditions the resistance increases as the square, it follows that if the mass continues to augment, there will come a time when the centrifugal force will be greater than the limits of the resistance and cohesion, and in consequence all the mass will yield to a certain degree.

The most resistant substance known to us, having a hundred millionth

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* Philos. Magaz., 1847, p. 194.

part of the volume of the earth, would be flattened if its rotation was as rapid as that of the surface of our globe. This incontestable fact is no proof against the supposition of a primitive fluidity; it rather shows us that the idea of fluidity is quite relative, for that which assumes a certain form upon our earth may become level upon a globe where the weight is greater. Spencer himself does not deny this fluidity, which is, moreover, now generally admitted.

At the commencement of the period at which we stopped in the history of our globe, the nucleus, composed of liquid and incandescent lava, possessed a uniform very high temperature. A dense atmosphere surrounded it, containing the elements of the present atmosphere, also substances not condensed, and all the water of the earth in a state of vapor. This uniform temperature of the incandescent lava could not continue indefinitely, for the liquids which were precipitated from the upper strata of the atmosphere, where they were condensed by the cold, decreased the heat by a new volatilization. This constant cooling of the surface of the nucleus determined the first congealment of its liquid mass.

The scoria formed by this congelation were broken and heaped up by the continual ebullition of the liquid sea of matter, by storms, which were of a violence in proportion to the chemical activity of the globe, and the denseness of the atmosphere and by the tides, produced by the attraction of the sun and moon. Their *débris* collected into floating islands, which were constantly increasing in extent and number, and at last by their union formed the first, but still greatly-agitated, crust of the earth.

Sir William Thomson* has shown that the central heat can have no influence upon the temperature of the surface of the globe ten thousand years after the definite formation of the terrestrial crust. This fact has its cause in the want of conductibility of heat of the eruptive or plutonian rocks. As an instance of this, one may walk with impunity upon a bed of lava, a few days after an eruption, while at the depth of only a few feet the lava is still incandescent, and so continues, sometimes for nearly a century.† The thermal sources and the eruptions of lava may have maintained the temperature at a very high degree, even during more recent times; and it is probable that for three or four millions of years vegetation was affected by the high temperature of the soil whenever the roots penetrated more than a yard below the surface.‡

As soon as the central heat ceased to act upon the temperature of the surface of the globe and of the atmosphere, the precipitation of vapors must have become almost general. The temperature of the first water was undoubtedly high, on account of the great pressure of the atmosphere, of the heat liberated by condensation, and of the sensible influence of the still recent crust. This high temperature of the water facilitated

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* Phil. Mag., January, 1863, p. 8.

† L. Figuier, *La Terre avant le Déluge*, 1863, p. 35.

‡ Thomson, Phil. Mag., January, 1863.

the dissolution of the plutonian rocks, which were deposited under the form of unstratified sediment in proportion as the water cooled.

After the precipitation of the water, calm did not reign upon the surface of the earth; violent reactions evinced the powerful but irregular struggle of the central forces. The origin of these forces is found in the constant loss of the heat of the globe. According to Reich and Bailey the density of the earth must be between 5.44 and 5.67. It is, then, greater toward the center than at the surface. This is evident from the mean density of the sedimentary and eruptive rocks of the crust.

We ought not to be surprised at the great density of the central strata; on the contrary, if we take into account the compressibility of liquids, and the enormous pressure the subterranean mass supports we will be astonished that it is not greater, and seek, with Lesley, a force sufficiently powerful to counterbalance this immense pressure. We know that the heat alone maintains bodies in a certain state of fluidity; but as there is a constant loss of heat, equilibrium must cease and the entire mass shrink in proportion to the loss of caloric. The terrestrial crust which passes from the soft to the liquid state contracts more than the total volume of the ignited mass; a cracking of the crust ensues and an ejection of melted and incandescent matter.

The sedimentary crust does not contract in any way. It sinks at certain points and rises at others, following the contraction of the solid crust it covers. Hence the heaping up in places, the rents and irregularities of a surface once perfectly united and level. All these inequalities are so many new agents for the circulation of the water at the surface of the globe, which by disaggregation and denudation furnishes material for the filling up of oceanic depressions.

The appearance of organisms in their most simple forms soon followed the formation of the sedimentary strata. This was a sign that the chaotic state which necessarily prevailed during the period of the precipitations of the first waters was approaching its end. We know little of the structure of these first organisms. They were only the precursors of others more perfect, which in their turn became the antecedents of the existence of beings of a still higher order.

There have been various efforts made to estimate the age of the earth, at least since the commencement of the sedimentary formations. Humboldt has said that geologists by their hypotheses and their conclusions penetrate into spaces and times which are far beyond the limits of our observation. But it should not be forgotten that if in this way they can arrive at a certain probability or relative certainty, it is rarely accorded them to settle their conclusions upon indisputable and necessary data, and therefore we cannot place entire faith in the estimations of the age of the terrestrial crust. Mr. Bischof has endeavored to show by the cooling of basalt and of lava that the earth has taken nine millions of years to cool down to the point it is at present, provided it be accepted that the Coal period required a temperature of from 27° to 28° C., and that the temperature of our day is from 7° to 15° at the mean. Gibbert has calculated the duration of the same period to be five millions of years. But why admit a temperature of 27° for the carboniferous period? The preponderance alone of the *Cryptogames* over the *Phanerogames* does not justify this estimate, as proves the flora of New Zealand, which is almost exclusively cryptogamic. Moreover the cooling of a mass of basalt takes place in a medium and under conditions quite different from those which determine the cooling of the earth. It is, then, with little hope of attaining the truth that we try to calculate the duration of geological ages. We must, however, admit that they were immense compared with our short existence, and in every case greater than the figures mentioned.

CHAPTER II.

CENTRAL HEAT.

The central heat is a constant source of forces, which, in different ways, act upon the crust of the globe.

The contraction of the solid crust, the cracking of this crust, and the escape of incandescent matter are direct consequences of the loss of this heat. The plications, the faults, the elevations and depressions of the sedimentary crust take place because the sediments can no more contract, but, on account of their weight, sink at certain points of the solid nucleus.

From these two kinds of forces there result a series of phenomena, of which the rising and sinking of entire countries, earthquakes, and volcanic eruptions are the most important.

The actuality of these risings and sinkings of the crust of the globe has been confirmed in so many ways that all savans now agree in attributing to them a large part in the successive modifications of the surface of the earth, and in the raising of the continents. If there were no other convincing proof, the fact that the mountains are, on an average, 10,000 meters above the mean of the oceanic depressions would confirm the idea that these masses cannot be of marine formation, but are the product of a central force—of an action slow but constant, rarely sudden or violent.

Upheavals and subsidences are observable at many points of the globe, and some even are taking place under our eyes, but so slowly that the effect is perceptible only after a long period of action. Thus it is proved that the northern part of Sweden is rising so rapidly that we may foresee the time when the Gulf of Bothnia will be completely dry. This elevation diminishes toward the southern part of this country, and there is even a sinking of the shores of Germany, of the islands of

Denmark and of Norway. Greenland is also sinking, as was proved after the grand breaking up of the ice in 1815. The ancient dwellings then found were washed by the sea, and in some cases entirely submerged, which was evidently not the case when, in the fifteenth century, they were inhabited by the Danish colonists. A striking example of an alternate elevation and depression is furnished us by the columns of the temple of Serapis, not far from Pizzoli, on the Gulf of Baiæ. The foundation of this temple is at present below the level of the sea, and the water covers it according to its height, from 30 to 45 centimeters, (12 to 18 inches.) Three large columns, of Greek marble, about 8.5 meters, (28 feet,) are still standing; others lie broken and scattered along the shore. All these columns are perforated at the same height by pholadites, which only at the level of the water attack the calcareous rocks of the coast. The space where this perforation was accomplished is very narrow, its upper and lower limits forming a zone of from 2.25 meters to 2.56 meters (7½ to 8½ feet) in width. The lower limit with the large columns is at a height of 2.84 meters, (9¼ feet;) with the smaller and more elevated columns of the temple it is only about half as high. The lower part of the columns is perfectly well preserved, even retaining the polish, while the part above the perforated zone is much decomposed, as all calcareous matter exposed to the influence of the waves, the air, and the sun. When, in 1749, this temple was discovered, only the upper part of the columns emerged from the volcanic sand and scoria deposited by the sea. It was necessary to clear away the material collected, in order to obtain this proof of a prolonged continuation of the water at a height which necessarily implies a rising of the entire coast, since so great a change in the level of the sea, it is evident, has not taken place on other parts of the Mediterranean.*

The Australian continent gives us, also, a proof of a contemporaneous rising. Thus Mr. Becker has shown from the examination of a number of facts that in the space of twelve months Hudson's Bay was elevated four inches. The pole of the pavilion on the shore whose foot was bathed by the sea five years before, at the time of the observations, was at a considerable distance from the water, separated from it by a lawn of vigorous vegetation and covered with tents and houses. The celebrated navigator, Flinders, made in 1802 bathymetric observations upon the south coast of Australia, and his charts, remarkable for their precision, were regarded as authority with the English marine. But soon it was found that, in the bay of Lacépède, for example, where Flinders had marked 10 fathoms there were only 7; this was a rising of 18 feet in fifty-six years, which gives four inches a year. The quay of Melbourne is six feet higher than it was twenty years ago, and the inundations to which this city were exposed have ceased, on account of this elevation. M. Becker concludes that the whole Australian continent is relatively

* H. Girard, *Briefe über Al. v. Humboldt, Kosmos,* t. iv, 2e partie, p. 88.

recent, and that it must have been covered by the sea at no very distant period. He supports this opinion by the accounts of travelers who have visited Central Australia. They all declare the existence of a vast surface in the center of the continent, surrounded with mountains and covered with sand, in which are found the broken shells and the carapaces of crustacea as well preserved as if they were recent. The strange flora and fauna of Australia, the salt lakes of its interior, as well as the presence, frequently contested, of the more recent Tertiary deposits, alike confirm this supposition.*

Another proof of a slow rising is given us by the small island of Santa Maria, not far from the island of Conception. Captain Fitz Roy found, from the traces produced by the erosion of the sea and from the perforations of the *Pholadites* that the northern part of the island has been elevated 10 feet, while the southern part has risen only 8 feet, above the level of the ocean. We cannot attribute this rising to a retreat of the sea, for the unequal elevation of the ancient line of erosion would be then unexplained. Mr. Darwin attributes, also, to a general rising of the continent of South America the beds of shells he observed at a height of from 4 to 5 English feet.

The shores of France, also, offer examples of an oscillation of the surface of the earth. In the vicinity of Bourgneuf, not far from La Rochelle, are the remains of a ship wrecked in 1752 upon an oyster bank along the coast. To-day these remains are found surrounded by cultivated fields, and 4.2 meters (13½ feet) above the mean level of the ocean. The neighborhood has gained in the course of twenty-five years more than a thousand acres of ground merely by the rising of the coast.† Normandy and Bretagne, on the contrary, are sinking, although very slowly. We find there are on the coast of Greenland submerged edifices which date from the eighth century.‡

We must not forget that, according to an hypothesis generally admitted in regard to the increase of coral formations, the presence of the latter in a sea indicates a slow sinking of the bottom of the ocean. The researches of Darwin upon these formations in Polynesia show that the corals live ordinarily only at a depth of from 34 to 43 meters. Now, on examining the coral islands, we find that the calcareous formations of the corals descend in abrupt slopes 335 meters below the level of the sea. As the corals cannot live at such a depth, it must have been the sinking of the bed of the ocean which caused them to descend.

These facts are sufficient to show that the plications and the rising of the sedimentary crust have altered greatly the surface of the globe. We will see that volcanic force, which is a more direct result of the central heat, produces the same effects. It is these two forces, heat and volcanic action, which have raised enormous masses of granite to the

* *The Annals and Magazine of Natural History*, vol. xvi, 3d ser., 1865, p. 333.

† Girard, *op. cit.*, p. 101.

‡ *Ibid.*, p. 110.

height of the Himalayas, the Andes, the Alps, and the Pyrenees. Only their intensity has not been always the same; this is greater in proportion as the crust where the rupture takes place is stronger. On account of its slight thickness the first crust of the earth offered very little resistance to the escape of the ignited substances, which easily forced a passage through the large rifts and cracks in its surface, and, as the first sedimentary strata were still plastic, they followed easily the contraction of the solid crust. To-day the thickness of this envelope is estimated at more than 25 miles; its resistance, therefore, is much greater, and continues to increase by new eruptions and new solidifications of ignited and fluid substances. On this account the more recent geological periods have been marked by fewer of the catalysms, indicated by the formation of mountain chains, but their intensity and violence have been proportionately greater, giving rise to the Andes and to the mountains of Central Asia, which are more recent than the mountain systems of Europe, and relatively much more important.

Earthquakes are phenomena which most frequently accompany all modification of the crust of the globe. What we know of their nature is that they are undulations of the ground, sometimes more, sometimes less elastic. The starting-point of these waves is in the interior of the earth, often very near the surface, (at 3,400 meters, or 11,000 feet,) sometimes at a very great depth, in which case a circle is shaken, including many countries and entire seas. The earthquake which, on the 31st of November, 1755, destroyed the city of Lisbon, was felt in Labrador, and from Canada to the Carolinas, in the Antilles, Morocco, the north of Italy, Germany, a part of Russia, the south of Sweden and of Norway, and England felt its influence. The district affected by this earthquake extended approximately 100° in longitude and 50° in latitude, and comprised a surface of 325 square myriameters, (12,500 square miles.) Other districts affected by earthquakes have been quite equal to this one in extent. Thus the region of earthquakes on the Mediterranean extends from the Azores to beyond Lake Baikal.

The causes of earthquakes may then vary in nature, according to the depth from which they proceed, although in general their origin is the same; but, whatever may be their cause, we can, through analogy of their effects, make use of some mechanical laws to explain the phenomena which accompany them.

It is known that in a homogeneous and elastic medium the sum of the active forces remains constant and is propagated in all directions. In applying this law to earthquakes, it follows very simply that, first, the point most agitated is also the nearest to the origin of the agitation, and that the points at equal distance from the center of the movement are similarly affected, according to the principle that the effects of a blow transmitted upon different points are under identical conditions as the sine of the angle at which the surface is attained;* and, second, that

* Prof. Pfaff, *Zeitschrift der deutsch. geolog. Gesellsch.*, 1860, p. 453.

the point nearest to the origin of agitation is the first to be influenced by the commotion which is transmitted to other points in isochronal circles.

Close observation of these isochronal circles would undoubtedly contribute much to the knowledge of the nature of earthquakes. For this end meteorological stations should be provided with instruments for determining the direction and intensity of these phenomena. But all the instruments for this purpose, hitherto proposed, fail either because they are too complicated or on account of their want of accuracy, and the seismometers employed are for the most part not as good as a bottle with the inside polish taken off and filled with a liquid slightly colored. Such a bottle, suitably placed in a quiet spot, will indicate, in case of a commotion, by the highest points of the side wet and colored, the direction of the current, and by the width of the zone the relative intensity for the same place.

Many scientists distinguish in the motion of earthquakes an agitation by shocks, a movement of undulation, and a movement of rotation, (or of twisting.) The centers of commotion of the crust, where the effects are the most violent, sometimes present the phenomenon of a shock from below upward. During the great earthquake which, in 1783, devastated Southern Calabria and the city of Messina, blocks of granite were seen to jump up without changing place, while men and even animals were thrown into the air and deposited in some cases upon much higher ground. When the earthquake in 1797 destroyed the city of Reobamba, situated to the south of Quito, the corpses of several of the former inhabitants were thrown upon the hill *La Cullca*, a height of several hundred feet. It is said that during the earthquake in Chili, which took place on the 7th of November, 1837, a pole sunk 8.5 meters (28 feet) in the ground, and sustained by iron bars, was violently thrown upward, leaving a deep hole.*

The undulatory movement of the ground is more frequent than the movement by shocks, and its relation to the latter movement is analogous to the undulation of a surface of water compared with the spot at which a body falls into it; with the difference that the surface of the soil receives the first shock from below upward. The surface of the ground is agitated as a liquid surface. Thus, to several eye-witnesses of the earthquake of Lisbon, the buildings of that city appeared to rise and fall like a flotilla with the waves of a heavy sea. The movement of the ground produces upon the mind an effect well described by Humboldt. "This impression," says the author of the *Cosmos*, "does not in my opinion proceed from the memory of the numerous similar catastrophes recorded by history, which then crowd upon the imagination. What affects us is, that we lose suddenly our innate confidence in the stability of the ground. From our infancy we are habituated to the contrast of the mobility of the water with the immobility of the

* Girard, *op. cit.*, p. 8.

ground. The testimony of our senses strengthens our security. Does this solid, and as we supposed thoroughly reliable surface commence to tremble, a moment suffices to destroy the experience of a life-time. An unknown power is suddenly revealed; the calm of nature was only an illusion, and we feel ourselves violently thrown back into a chaos of destructive forces. Then every noise, every breath of the wind, excites atttention; we distrust above all the earth we tread upon. Even the animals are disturbed by the unusual phenomenon, and accompany every shock with cries and bellows, while the birds indicate the approach of the earthquake by their uncertain and terrified flight."

The third kind of oscillation of the ground is probably only a modification of the undulatory movement. It is known that there are often many spots within the radius of activity of an earthquake which remain intact, an island amidst countries destroyed. This is because the ground is not of a character to transmit the movement. Suppose then a disposition of similar ground in a horizontal direction to retard the progress of the waves at one angle more than at another, the rotary movement would be produced which curves the rectilinear boundaries of plantations and changes the orientation of buildings. The triangular obelisk of the Episcopal square at Agram was, three years ago, a curious example of this phenomenon. The angles of the superposed parts of the obelisk were displaced horizontally at least 25°. A reparation of the obelisk has effaced this proof of the existence of the rotary movement, which, however, is neither as frequent nor as important as the two others.

Thus far we have said nothing of the cause of earthquakes. Is this cause the giving way of subterranean caverns, or the sinking of rocky masses? Is it the effect of the dilation of the crystals which are formed in a supersaturated solution, as Mr. Volger believes, or is it a subterranean storm, as was declared by the ancient philosophers?

All these hypotheses, and many others that have been advanced upon this subject, are far from being entirely false, but their application can be only very limited and often purely local. Now we require a theory which finds a reason for the phenomena in the physical constitution of the earth; an agent whose powerful action can be proved in the geological periods and whose important effects may be foreseen in the future.

Here, as before, we have recourse to the central heat, which maintains in a state of liquidity the greater part of the terrestrial mass, except a thin solid envelope which covers it. The supposition that this is the cause we are seeking coincides with what we know of the mobility of the crust of the globe. We will say, then, that it is the loss of the central heat which produces directly or indirectly ruptures and sinkings of the terrestrial crust, the mechanical effects of which are transmitted by waves over great surfaces and give rise to earthquakes. It should be added that many other circumstances may modify this action. Thus earthquakes are most frequently felt in the vicinity of the sea and of volcanoes, as in Italy, in Asia Minor, in the western part of South America, in the Sunda Islands, and the Philippines, &c., rarely in the center of continents. The winter seems most favorable for the production of the phenomenon, which fact is explained by the contraction of the crust caused by the cold. As the moon must exercise upon the liquid mass of the earth an effect analogous to the tides, Perry has attentively observed the phenomena of earthquakes with reference to this action. By the comparison of more than seven thousand observations, made at the commencement of this century, this savan found that earthquakes are in fact more frequent at the perigee than at the apogee; they are also more frequent when the moon passes the meridian than at any other relative position of the satellite to a given place.*

It seems, however, that, contrary to what has been assumed, earthquakes do not depend upon the state of the atmosphere. The proximity of large bodies of water is not necessary for the production of this phenomenon. Attempts have been made to demonstrate the electric nature of these commotions of the crust, but without success in establishing, even upon general facts, the exposition of this hypothesis.† The magnetic activity of the earth has equally no relation with earthquakes, and the deviation of the magnetic needle at the place alone where the commotion is felt is a proof that this perturbation of the needle must be attributed to local electric currents, which may in their turn result from the mechanical action employed in the production of the earthquake. All things, then, considered, the commotions of the crust upon which we live depend principally upon the chemical and calorific modifications of the liquid and incandescent mass, and the nature of the solid crust. They are partially influenced by the substance of the nearest planets, and by the cold, which determines sometimes their frequency. The other causes are quite accessory and at present hardly admit of generalization.

Another series of phenomena, very often in intimate relation with earthquakes, have their source in the incessant contraction of the solid envelope of the globe. As the chemical activity of the fluid and ignited mass is not destroyed, its effects are combined with the effects of the contraction of the crust; hence the fractures, the crevasses in the solid envelope, followed by eruptions of lava, basalt, and trachyte. We may say, then, with Humboldt, that volcanic activity is only the reaction of the interior of a planet upon its crust.

One is often astonished that the center of the earth can furnish so much material for volcanic eruptions, but an examination of the subject shows that no great contraction of the crust is required to supply all these eruptions. The greatest discharges of lava contain rarely more than a thousand cubic meters, and seldom as much. If we imagine this substance extended over the surface of the earth, the stratum thus formed

Institute, No. 1067, p. 201.

† Girard, *Briefe üb. Al. v Humboldt's Kosmos*, p. 145.

would hardly amount to the five-hundredth of a millimeter (the 12,500th of an inch) in thickness. A contraction, then, of the crust which would shorten the radius of the globe a millimeter ($\frac{1}{25}$ inch) would be sufficient to produce five hundred powerful emissions of lava, and a contraction of three centimeters (1.18 inch) would be enough to furnish lava for all the eruptions history has recorded for three thousand years.*

As to the intimate relation which exists often between earthquakes and volcanic eruptions, there are so many proofs of it that even the common mind has learned to recognize their connection. Thus when the Italian peasant sees Vesuvius and Etna smoking and discharging vapors, he has no fear for his security. But when these natural processes cease to give passage to the gas and the vapors which are continually disengaged from the interior of the globe; when calm succeeds to the feeble detonations which accompany these manifestations, then he is filled with anxiety and dread, for he knows that a violent eruption will be the consequence of this apparent repose, and that earthquakes will ravage vast extents of the surrounding country. Let us cite some examples of this relation between the two phenomena. Humboldt relates that the volcano Paola, situated to the north of Quito, vomited thick, black smoke at the commencement of the year 1797. On the 4th of February of the same year the smoke suddenly ceased, but precisely at the same time occurred, fourteen miles more to the south, the terrible earthquake of Kiobamba, one of the most violent which had ever devastated the plateau of Quito. Scarcely was this over than the western Antilles were troubled by an earthquake which lasted six months, and ceased on the 27th of September with the eruption of the volcano of Guadeloupe, until then inactive. When the eruption of this volcano ceased, new shocks were felt in South America, which ended only with the destruction of Cumana, on the 14th of December of the same year.

Volcanic openings, or mouths, are not irregularly distributed over the surface of the globe; they are most frequently parallel to the principal lines of fracture of the crust, and then they form part of mountain-chains. They are rarely isolated. It is worthy of remark there are few volcanic centers still active which are at a great distance from the sea. What was said of earthquakes may also be said of volcanoes: they are more frequent in maritime districts, for wherever the sea has retired during the geological periods, the volcanoes then active have ceased to be so. Witness the extinct volcanoes of Auvergne, of the Rhine, of Transylvania, of Bosnia, and other volcanic cones of the Andes, of Abyssinia, &c. Still we have no reason for refusing the testimony of Humboldt as to the existence of volcanoes in Central Asia. "If active volcanoes," says this savan, "are almost always in the neighborhood of the coast, this is due less to the influence of the water of the sea, than to the facility with which the crust of the globe is ruptured, at a place where the declivity of the continents toward the sea, in carrying off the

* Pouchet, *L'Univers*, note 113, p. 144.

sedimentary strata, facilitates the fracture." Moreover, in the chain of the Southern Andes we find the volcano Tolima, 5,613 meters (3½ miles) in height and distant about 200 miles from the sea, which experienced a great eruption on the 12th of March, 1595. But this maximum of distance of an active volcano upon the American continent is hardly the tenth part of that at which we find in Central Asia the active volcanoes of the chain of Thian-Chan, which, according to reliable information, have emitted flames, lava, and pumice-stone since the first century of our era. "The hesitation," says M. d'Archiac,* "to admit the existence of these volcanoes because there are oil mines which, if on fire, would present similar phenomena, is evidently forced, and rather a supposition to sustain an hypothesis, which must, however, yield to facts which cannot be doubted."

This reflection applies especially to the partisans of the hypothesis of Gay-Lussac, who are numerous and strong, on account of the facility with which this theory is deduced from the two principal forces of the earth, the sea and the central fire. As the hypothesis has its reasonable side, we will give some of its principal features.

At the commencement of this century it was considered that proximity to the sea was indispensable for the production of volcanic phenomena. Examination of the products of the eruptions persuaded the French chemist that they are the result of a reaction of the sea-water, which penetrates through fissures to great depths, upon liquid and incandescent rocks, for the most part of silicates of potassium and aluminum. In this case the different chlorides of the sea-water act upon the silicates and produce by their decomposition, and a recomposition more in accordance with their affinities, such an over-increase of heat that a volatilization of the water, in spite of the enormous pressure, is the consequence. The steam forces its way through the fractured crust, and carries with it the substances melted by its passage, such as trachyte, basalt, and, at the present period, lava. In more recent times an attempt has been made to attach the hypothesis of Gay-Lussac to that of Mr. Elie de Beaumont, who attributes volcanic eruptions to a kind of effervescence which the gases contained in melted matter produce as soon as the pressure of the crust is removed by its fracture. By virtue of this effervescence, which causes the melted matter to rise wherever the pressure is least, the sedimentary andp rimitive rocks are injected with incandescent masses, sometimes of considerable volume. It is then that water is supposed to intervene in these passages of injection; it reacts upon the incandescent rocks, and from this reaction results a volcanic activity, less productive in the outflowing of lava, but not less formidable on account of the volcanic storms it occasions.

The mud-volcanoes are undoubtedly the last effort of volcanic activity. M. Hochstetter has shown† us that the former eruptions of the

* *Histoire des progrès de la géologie*, t. 1, p. 181.

† *Die Vulkane Javas*, Sitzungsberichte der Wiener Akad., xxxvi, p. 128.

volcanoes of Java have given place to emanations formed only of the *debris* of ancient eruptive rocks mingled with cinders, and reduced to a pasty condition by the water which penetrates into the interior of the crater. He establishes three periods of activity for these volcanoes, characterized, first, by emissions of trachytic lava (oligoklasaugit) in the incandescent but pasty condition, which extend horizontally in strata and form the volcanic cone; second, by the flowing out of trachytic rarely basaltic lava, in a fluid state; and third, by the expulsion of cinders, sand, and angular fragments of incandescent lava, which takes place still in our day. The accumulation of water in the craters causes the eruptions of mud. Very remarkable are the aqueous eruptions observed in South America. Bouguer reports that at the time of the eruption of the volcano Cotopaxi, which occurred in 1742, a disastrous inundation was attributed to the water thrown up by the volcano. An analogous phenomenon was presented at Lancerotte, one of the Canary Islands. There it could not be said, as in the case preceding, that the water came from the melting of the snow accumulated upon the cone of the volcano, for, in the first place, there was no snow upon the island, and, in the second, the water was seen to come out of several of the craters in a state of activity.*

According to M. Saint-Claire-Deville,† the phases of volcanic action are three in number, first, *phase of great activity*, marked by violent eruptions, such as Vesuvius has experienced several times within eighteen centuries; second, *phase of mean activity* or *strombolian phase*, characterized by slight eruptions, succeeding each other at short intervals; these eruptions have their seat at the summit of the cone or in its immediate neighborhood; third, phase of *least activity or sulphureous phase*, when only aqueous vapors are disengaged, accompanied, according to the intensity of the eruption, with chlorhydric, sulphurous, sulphydric carbonic acids, hydrogen gas, and carbureted hydrogen. Not only do we observe a certain succession of these products during the sulphureous phase, but we find also that they are disengaged at a determinate distance from the opening and in concentric circles. Nearest the mouth the chlorhydric acid, then the sulphurous acid, the sulphydric acid, the carbonic acid, and lastly the carbureted hydrogen. This succession seems to indicate that the compounds of sulphur and carbon, which are thus disengaged, around the cone of the eruption, are only metamorphic products, which are formed by action of the heat from the lava, arrested in the volcanic passages, upon the rocks impregnated with water, which contain sulphur and carbon in a state of combination.

Volcanoes must have existed at every age of the world, but of course they differed greatly in importance, when the terrestrial crust was hardly formed, until now when it is about 40 kilometers (25 miles) in thickness. However, M. d'Ormalius d'Halloy affirms that volcanoes did not exist before the Quaternary period.‡ Ami Boué, on the contrary,

* Della Torre, *Storia et fenomeni del Vesuvio*, p. 82. †*Comptes Rendus*, t. lxvi, p. 803.

‡*Bulletin of the Geological Society of France*, t. xi, p. 80, 1853.

opposes the opinion that the ancient Plutonic rocks were produced by the simple escape of fluid matter through fissures in the crust, and that all the ancient eruptions took place under the sea. He believes that there have always been islands, which, like the islands of Oceanica in our day, are centers of great eruptions. As to the sedimentary strata which cover ancient craters, and which d'Ormalius mentioned in favor of his view, a depresssion of these islands below the level of the sea would perfectly account for the marine deposits upon the trachytes and the basalts. Taking the lava as an essential character of the volcanoes, d'Ormalius, moreover, denies their existence, on account of the entire absence of lava in geological eras anterior to the Quaternary period. This fact does not prove the absence of eruptions, but merely a change in the eruptive matter, which might result from the greater depth of the strata from which the lavas proceed and from the increased pressure they must support, which cannot but affect the nature of the igneous rocks. Ami Boué thought eruptive craters existed as far back as the Secondary period, and even before the Carboniferous period.

The formation of volcanic cones and the craters they contain has long been a subject of discussion. De Buch advances the theory of the formation of craters by gaseous emanations, proceeding from the interior of the globe. These emanations, he says, raise the sedimentary strata like a bubble or blister, which, in bursting, forms a circular cavity by the accumulation of the *débris*. The maps of Teneriffe and of Palme, with which he supported his theory, led to a no less important discussion in regard to the marine formation of the basalts, according to the Neptunian theory of Werner. The views of De Buch prevail in the celebrated descriptions of Etna and of Vesuvius by the French savans Élie de Beaumont and Dufresnoy. Sir Charles Lyell combats this theory in his *Principles of Geology*, to-day universally esteemed. Fr. Hoffmann, who saw arise from the bosom of the sea the island of Ferdinandea, opposed to the theory of De Buch the formation of craters by accumulation of scoria, sand, and volcanic ashes.* But let us remark, in passing, these hills of sand and ashes are sometimes hundreds of feet in height, such as those formed by a very violent volcanic action in the middle of a great plain in the State of Nicaragua,† or I may say even such as the great Chimborazo, if we admit the consolidation of sand and cinders or ashes into solid rock.

The effects of volcanic action are very great, and, as we shall show, they may contribute to the modification of the crust of the globe.

On the 12th of July, 1831, suddenly arose, near the bank called Nérita, between the Pantellaria islands and the coast of Sciacca, in Sicily, a volcano, from out of a sea from a hundred and forty to two hundred meters (450 to 650 feet) in depth. It was formed of scoria; was about three leagues in extent, and about sixty yards in height. It disap-

* D. H. von Dechen, *L. v. Buch, Sein Einfluss auf die Entwickelung der Geognosie*, Bonn, 1853, pp. 14, 15.

† Ramon de la Sagra, *Comptes Rendus*, t. lxvi, p. 481.

peared into the sea on the 28th of December, 1831. Fr. Hoffmann was at that time in Sicily, and made a report of it in the *Annales de Poggendorf.* It was the origin of his theory of the accumulation of volcanic ashes. Spratt announced in 1862 that the island again arose from the deep, and that it was hardly three meters or ten feet above the level of the sea.*

Submarine eruptions are quite frequent. The navigators who have observed them describe the phenomenon in brilliant colors and with a vivacity of expression, which evinces the powerful impression made upon their minds. In fact, the boiling sea, the blackened waters thick with ashes, the boisterous waves, the rise and fall of the columns of water shot into the air, the rumbling of thunder from the electrified clouds, form a wild but harmonious picture, of which it is difficult to catch the details, on account of the constant and rapid change of scene.

Continental eruptions in the midst of a large plain are not more rare. Humboldt has left a description of the eruption which formed the volcano Jurullo. Six days' journey from the city of Mexico, a large plantation of wheat was agitated for two months by a violent trembling of the earth. Finally it began to undulate like a sea under the influence of a strong wind, and a thousand mouths were opened vomiting flames and lava. Then arose, with six other elevations, the volcano called Jurullo, which soon attained a height of 520 meters (1,700 feet) and vomited torrents of lava.†

The hot springs, the geysers, seem to have direct connection with earthquakes and volcanic phenomena. The hot springs of Western Bohemia, during the earthquake of Lisbon, experienced several times a loss of water, alternating with an increase of double their usual supply. At the same time several lakes of Carneole became suddenly dry, but filled of themselves a short time after. The same phenomenon was observed several times in Calabria and in America during volcanic eruptions. This phenomenon may be explained in several ways, but we confine ourselves to the following solution, which is sustained by a large number of well-established facts:

It appears, from the observations of Dr. Cartellieri upon the variation in the supply of the spring called *Franzensquelle* at Eger,* that this supply is in inverse proportion to the barometric pressure. This fact admits of the following deduction. We must suppose, antecedently, a constant force, which causes the water to spout up from the spring, and this force must be independent of the barometric pressure, for if it were not, it would not act in a contrary direction. We may then compare this phenomenon to a fountain in a vacuum, placed under the receiver of a pneumatic pump, in which the air may be alternately compressed and

* Ch. Ehrenberg, *Die bei Sicilien sich neuerlichst wieder hebende Ferdinandea Insel,* Berliner Monatsberichte, 1863, p. 486, 489.

† L. Figuier, *La Terre avant le Deluge*, p. 372.

‡ Nowak, *Sitzungsberichte der böhmischen Gesellschaft der Wissenschaften*, Prag, 1864, t. 1, p. 144.

rarified. If we suppose the water rushes out in a fine jet, this will increase in height when the air is rarified by a few strokes of the piston, and it will diminish, on the contrary, when the air is compressed. We have before us exactly the image of what takes place in nature, if we admit that the reservoirs of most springs are cavities produced by the separation of sedimentary strata, following a commotion of the crust or a sinking of the inferior strata, while the upper strata remained unmoved, or under other circumstances were elevated. These excavations fill with water, which does not vary in volume as long as the surrounding ground is in repose. But if a slow upward movement diminishes the capacity of these reservoirs, the water they contain will be driven forth with more or less violence according to the rapidity of the upward movement. An earthquake may then produce such a pressure upon the waters of the reservoir that it will be driven out with great force and may sometimes occasion extensive inundations. In this way may be explained the inundation of the island of Lacerotte, of which we have already spoken. In other cases the commotion may produce large subterranean cavities, which would absorb the water of lakes and rivers.

The geysers of Iceland and the torpedoes of Brazil are springs of another origin. Their waters penetrate by fissures to the incandescent rocks of the volcanic outlets. There, heated by contact with the ignited masses, they dissolve large quantities of silica, and, driven by the steam which is formed, they rush to the surface and there, in cooling, deposit the silica. To the action of hot springs we must attribute the formation of many rocks, generally considered of volcanic origin. Thus hypersthénite has been hitherto described as an eruptive rock, but is found, according to the report of the geological commission of Canada, in the state of sedimentary rock in several localities in that country. The sedimentary origin of many granites, syenites, diorites, and dolorites is equally established by the savans of this commission.

We have only to say, in terminating our views of plutonian forces, that the metamorphism, to which is attributed all change of aggregation of a rock, should be reduced to its normal proportions, for the oil-beds—the saccharoid marbles—are found far from all eruptive rocks, and are continued often by masses which do not bear the same characteristics. In many cases the influence of chemical agents, of enormous pressure, and of heat alter the lower strata of the crust sufficiently to explain some cases of metamorphism.

We have endeavored to show that the central heat is a constant source of forces which have modified the surface of the globe and brought it to its present condition. These changes were produced very slowly on account of certain very simple laws, which are still in force. Without the necessary connection of these forces, which renders it possible to submit their effects to continuous observations and to deduce from them the bases of the theory of the physical constitution of the earth, geology as a science could not exist; it would be undistinguishable from petrology or palæontology, upon which it is founded.

CHAPTER III.

THE FLUID ENVELOPE OF THE EARTH.

The formation of the crust of the earth is controlled by two powerful agents, one of which is known to us as the force of central heat, and the other has for its domain the atmosphere and the sea, and for principal motive-power solar heat and its unequal distribution at the surface of the globe. Such is the present state of the earth, but these conditions have not always been the same, for the influence of the solar heat is relatively recent, while for a long time the atmosphere was affected only by terrestrial heat, of which it was the medium. When the influence of this heat reached almost its limit, most of the vapors contained in the atmosphere were precipitated, and from the first drop of water which fell upon the still burning surface of the earth to the first ray of sunlight which shone upon the ocean in the full majesty of its power is the period when the geologist must look for the greatest manifestation of the plutonian forces upon the crust of the globe. It is also at this epoch that the formation of most of the rocks occurred, which for a long time have been considered of eruptive character. Further consideration of the necessarily greater activity of the atmosphere and of the sea at this early stage of the world's history, and of the composition of these rocks, will give us some light as to their character.

The temperature of the atmosphere at the time of the precipitation of the first waters was still considerable, for to the heat proceeding from the radiation of the earth was added the heat resulting from the condensation of the aqueous vapors. Now most bodies are more readily dissolved in warm water than in cold, and the same must have been the case on a grand scale when the sea was at an elevated temperature, and uniformly covered the face of the globe. This dissolving action extended to the silica and to the various silicates which form the base of the granite rocks. The first sea acted upon the crust of the earth by its excessive turbulence, by the rapid movement of its waters promoted by the continual oscillation of the crust itself, still very thin, and by the impulsion of a dense atmosphere in which the enormous evaporation and the condensation of the water gave rise to electrical discharges, to storms and whirlwinds, which are not possible under present conditions. Nothing could resist the destructive impetuosity of these waters which, breaking and overleaping all obstacles, became necessarily so overcharged with materials held in suspension, as to form at last only a thick muddy paste. Want of liquidity for a time arrested the movement of this mud, but as new waters were precipitated, equally agitated by the causes mentioned, it followed that in many cases this mud was taken up again and deposited anew. However, the impetuosity of these elements began at last to diminish, and in intervals of repose the stratified sediments were disposited.

According to one view, the sedimentary rocks of this first phase of the activity of the waters could be no other than the granites, the syenites, the serpentines, the porphyries, and other rocks reputed primitive or of plutonian nature. We suppose that they remained in a pasty condition as long as they were buried in the earth at a sufficient depth to be influenced by a temperature which maintained them in their primitive state; but they were hardened by losing the temperature and the water necessary to the solution of their siliceous cement, when by some pressure they were brought to the surface of the globe. This plasticity without incandescence explains clearly why there are no traces of metamorphism to be found in the rocks injected by granite veins, which would be the case if the rock had been liquid and incandescent. Other facts equally attest the aqueous origin of several granitic rocks.

Certain quartz, particularly the amethyst, lose their color so easily under the influence of heat, that we are led to the admission of the organic origin of color, which is irreconcilable with the hypothesis of the formation of quartz by dry means. M. Delesse has extended this theory of formation to all the granites. He says, "The existence in the granitic rocks of volatile organic material is alone sufficient to prove that they have not been submitted to very great heat; that they have not an igneous origin." His opinion has been confirmed by the investigations of M. Rose, which show that silica is found in two conditions: First, in the amorphous state, which could be produced by humid means and by dry means, with a density of 2.2 to 2.3; second, in the crystalline state, with a density of 2.6; it is the hyalin or the granite quartz which can only be formed by humid means or at least under the influence of water.*

These observations are of the highest importance, and will probably lead to an approximate solution of the question of the true origin of granitic rocks. At present the controversy in regard to this subject is not ended—quite the contrary.

In proportion as the influence of the sun upon the atmosphere became more apparent, the irregular action of the winds and oceanic currents must have given place, more and more, to a regular inclination of the fluids of the poles toward the equator, and *vice versa*. This regularity in the movements of the fluids was greatly affected by the incessant rising of the crust, which, in producing islands of variable extent, localized the denuding action of the current upon certain points, which, by their configuration, rendered the velocity of the waters greater. The materials carried away by the currents were dropped as soon as the motion of the waters ceased sufficiently, and formed deposits more or less homogeneous, according to the rapidity of the sedimentation.

After the emersion of islands and continents, the atmosphere continued the disaggregation of the eruptive and sedimentary rocks, through the influence of humidity, heat, and cold, by electricity and its chemical

* Favre, *Recherches géologiques*, t. iii, p. 307.

products, as well as by free carbonic acid, and by other substances less prevalent in the atmosphere.

The *débris* of these rocks were carried into the sea by the rains, proceeding from the condensation of vapors. The waters charged with material in suspension were united into streams and rivers, and emptied into lakes and seas. The denudation of the islands and continents, under the influence of atmospheric agents, is considerable. M. Croll * has calculated how much the American continent has been denuded in the entire Mississippi region. Knowing the quantity of material in suspension in the water ($\frac{1}{1500}$ of its weight), the amount of water annually emptied into the Gulf of Mexico, and the whole extent of the basin of which the waters empty into this river, this savant found that in 4,566 years 1 foot (304 millimeters) of earth is carried into the ocean. Taking into account the specific weight of the sediments (1.9) and of the crystalline rocks (2.5), we ought to bring the number of years to 6,000. As the mean height of the American continent is estimated by Humboldt at 748 feet (227 meters), the entire continent must at this rate be leveled and buried in the sea in 4,000,000 years; that is, if no ulterior uprising takes place. This denudation is not everywhere the same. It depends in general upon the mean elevation of the continent above the level of the sea. Thus the denudation of India, at least three times more rapid than that of North America, is easily accounted for by the great elevation of the Himalayan regions, which send down their waters through the tributary rivers of the Ganges and the Indus, and by the very frequent atmospherical precipitations which are the consequence of this elevation. The sources of the Ganges are found at a height of 3,962 meters, (2½ miles).

If we consider the effects of denudation during a time which is only a small fraction of the geological epochs, we may well ask how many times whole continents have been carried into the sea, to be sent forth again by the central forces of the earth's nucleus. We readily perceive that the various sediments have been several times destroyed and reformed by the effect of denudation; those primitive beds which have remained uninterrupted in the succession of their deposits owe their preservation to several circumstances, particularly to their being submerged, until the more recent epochs.

Speaking in general terms, we may say that the entire mass constituting all the mountains and continents, of a mean elevation of 307 meters (1,000 feet) above the level of the sea,† has been diminished by an amount of material sufficient to fill up an abyss six times the depth of the ocean. It must not be forgotten, however, that the continents are continually rising, and that certain parts of the ocean may, by upheaval, become land; likewise the continents may have been lowered at certain points, and submerged for a time, to appear again regenerated and enriched with new formations of strata.

* *On Geological Time*, etc., Philosoph. Magazine, vol. xxxv, 1868, p. 379.

† Humboldt, *Asie Centrale*, t. 1, pp. 182, 187.

Nothing resists the slow and continual action of marine waters, and whenever they do not create they inevitably destroy. The island of Helgoland, in the tenth century large and flourishing, is to-day reduced to a mere fraction of its former size, and at every tempest loses a constituent part of its frail existence. The destructive force of the sea is especially manifested upon abrupt projections, where the continuous shock of the waves is re-enforced by the action of the tides. In the Mediterranean, where the tides are nearly insensible, the action of the sea is governed by the submarine currents and by the prevailing winds. The oriental shores of the Adriatic are for the most part corroded, abrupt, and deeply indented, and the number of islands is very great. On the western shore, on the contrary, the sand beach is constantly increased, both by the sediment of the numerous rivers, having their source in the Alps, and by the *detritus* deposited at the bottom of the sea. This explains why Ravenna, which at the time of the Romans was a sea-port, is, at the present day, several leagues from the Adriatic. A similar phenomenon is manifested upon the coast of Western Flanders, where several villages, maritime in the middle ages, are now at a considerable distance from the sea, while other towns, now ports, can only be preserved by great labor from a similar fate.

At the bottom of the sea the deposit of sedimentary rocks is formed according to the nature of the material transported by the rivers or washed away by the action of the waves. An estimation somewhat uncertain in the present state of science gives to the sedimentary crust a mean thickness of 500 meters (1,600 feet) for the entire surface of our planet. We may, however, safely admit that this thickness exceeds a hundred meters (328 feet). Now as the sedimentation at the bottom of one of the most corrosive arms of the ocean, the British Channel, is only about four centimeters (about an inch and a half) a century,* we see that the process of sedimentation even in the ocean must be excessively slow, and require millions of centuries to form beds equal to the vast deposits of sandstone and calcareous matter. Is not the same slowness of action often observed in mountain regions, where a shallow sheet of water excavates a ravine of over a hundred yards in depth, while the hard rock is scarcely affected by a force much greater, but not persistent? It is not the momentary forces which produce the greatest changes at the surface and in the interior of our planet; it is the smaller but constant forces which, multiplied by an indefinite time, give those prodigious results which dazzle our senses, and of which we fail to discover the origin, because we cannot conceive of the time required to produce them.

The calcareous earths, and particularly the chalk, are not sediments of inorganic material, but rather deposits of organized *débris*, formed, according to Ehrenberg and several other micrographers, of the calcareous carapaces of microscopical animals. Great masses of the pure

* Houzeau, *Histoire du Sol de L'Europe*, Bruxelles, 1857, p. 135.

white of marble, of chalk and of the calcareous formations would be impossible without the intervention of organisms.* Marine water contains about 3.5 per cent. of salt, of which the sulphate of lime constitutes 4.617 per cent. A thousand parts in weight of marine water contains, then, 1.67 parts of sulphate of lime or of gypsum. Reckoning the mean depth of the sea at 2,000 meters, this quantity will correspond to 1,670,000,000,000 of kilograms (1,640,000,000 tons), and the specific gravity of gypsum being equal to 2.9, the total volume of this material will be represented by 578,000,000,000 of cubic meters (751,000,000,000 cubic yards). This quantity is greater than the mass of all the calcareous rocks of the continents, and sufficient material is afforded by it for the formation of new calcareous rocks. But as the carbonate of lime is not found in considerable quantities in marine water, and as the gypsum is the only calcareous compound so distributed, we must look for the source of the carbonate of lime, which is the chief constituent of the shells and the carapaces of marine animals. According to the various investigations in regard to this matter, plants decompose the gypsum, the sulphur of which serves in the formation of the albumen, the principal aliment of animals. The lime contained in the cells of the alimentary plants is put in circulation by the digestion of these plants, and after having contributed to the purification of the nourishing liquid which it deprives of its carbonic acid, it is secreted and forms the shells and the carapaces.

Among all the marine animals the smallest are the *Infusoria*, and especially the *Rhizopodes*, which contribute mostly to the formation of the calcareous strata.

The other organized deposits, particularly those which proceed from the *débris* of the *Testacea*, are formed for the most part along the sea-coast and principally upon the flat, sandy, muddy shallows, or very slight inclinations of quiet gulfs.† After the death of the shell animals the disengagement of the gas consequent upon their decomposition renders them specifically lighter, so that the constant play of the waves throws them readily either upon flat shores, where they are piled up with their shells unbroken, or upon steep cliffs, where the continual shock of the water reduces them to consolidated masses of *débris* which constitute the shell-marl. Submarine banks covered with *Testacea* of the genus *Ostrea* are constantly raised by the remains of these animals, while at the same time they gain in extent by the accumulation of the shells which fall from the bank and gradually fill up the surrounding depths.

The sand and clay transported by the rivers are generally the products of siliceous rocks and of the trituration of their *débris* encountered in the beds of rivers under the form of pebbles and gravel. The two

* Mohr, *Neue Ansicht über die Entstehung der Kalkgebirge,* Niederrhein. Sitzungsberichte, t. xxii, pp. 65, 99.

† D'Archiac, *Cours de Paléontologie Stratigraphique*, t. ii, p. 304.

substances are rarely found pure, as employed in the manufacture of glass and porcelain; they are generally mingled together in every proportion, and form the foundation of fertile soils. According to the cement which gives them their consistency to the period of their formation, and the proportion of their mixture, they form a great variety of rocks which are often difficult to specify, although the petrographic laws controlling the binary mixture of bodies are very simple.*

The action of the sea depends in a great measure upon the influence of the atmosphere. Now, as the atmosphere of past ages was of necessity denser than at the present time, this influence must have been greater. Before concluding from certain general phenomena that the atmosphere diminishes, and with it the action of the sea, we will say a few words upon its composition, which, being that of a mixture, is not invariable. M. A. Smith found that in Northern Scotland the quantity of oxygen contained in the air was the greatest, being 20.999 per cent., and that of carbonic acid the smallest, only 0.0336 per cent. M. Houzeau likewise made, during a long series of years, very exact observations in regard to the variability of the atmospheric elements, and found that the seasons sensibly influenced the proportions of the gases.†

The observations of M. Mènes‡ had previously made manifest that the quantity of carbonic acid varies with the seasons: In the month of December it undergoes no change; it increases until the month of May, decreases until the month of August, and reaches its maximum in the month of October. During the night the amount of carbonic acid is greater than during the day; it also increases after an abundant rain. From these facts we conclude that the quantity of carbonic acid in the atmosphere depends directly upon the vital activity of plants and animals; indeed, they regulate for the most part, if not entirely, its diffusion in certain parts of the globe at certain times of the year.

During the Coal period the atmosphere is supposed to have been especially charged with carbonic acid. This view appears to be corroborated by the rapid increase of the coal vegetation and by the remarkable thickness of the beds of carbonate of lime formed by marine animals. If, however, we compare the entire mass of carbon contained in the strata of the Coal period with the carbon at present in the atmosphere, we find that the latter much surpasses the fossil carbon; and we must admit with M. Ch. Lyell that the atmosphere of the Coal period differed very little in its composition from that which now surrounds our globe.§

In adopting the opinion of the English geologist, we do not wish to infer that the atmosphere is invariable in its elements and in its extent; on the contrary, we are led to believe in a variability both of the mass

* J. Roth, *Geolog. Zeitschrift*, t xvi, p. 675, 692.

† *Comptes Rendus*, t. lviii, p. 798.

‡ *Ibid.*, t. lvii, p. 155.

§ Ch. Lyell, *Travels in North America*, 1845, vol. i, pp. 150, 152.

and of the elements. According to Ebelmann, if the stratified rocks had contained 1 per cent. of protoxide of iron, this would have been sufficient to absorb all the oxygen of the air.* Now as iron is furnished from an inexhaustible and continuous source, the fall of meteors, the annual number of which is, according to M. Culvier Gravier, forty millions for the entire surface of the globe, this metal may, at a very distant period it is true, absorb all the oxygen gas of the earth.

Nitrogen also is diminishing in quantity. The electrical explosions during storms increase the affinity of oxygen for nitrogen, the result of which is an oxygenated compound of this gas. The latter, on contact with the air and with water, is transformed into nitric acid, which forms, with the alkalies and with ammonia, nitrates very widely distributed in nature. Nitrogen again is taken out of the air by guano and other analogous deposits. M. Rivero, estimating for the Chincha Islands the number of *Guanœs* at 264,000 only, found that these birds have been able, in six thousand years, to form the deposit of guano of these islands which is estimated at thirty-six millions of tons. As the *Guanœs* feed upon fishes, and as the latter contain only 2.3 per cent. of nitrogen, while the guano of Peru contains 14 per cent., M. Boussingault has concluded that 10 kilograms (22 pounds) of guano proceed from 600 kilograms (1,320 pounds) of sea-fishes, and that the 268,000,000 quintals of guano (26,000,000 tons) are equivalent in capacity of nitrogen to 2,268,000,000 quintals (223,000,000 tons) of fishes. The 53,000,000 quintals (5,000,000 tons) of nitrogen must have been taken out of the atmosphere, as we know of no other primitive source of this element. M. D'Archiac † has observed that the nitrogen withdrawn from the atmosphere cannot unassisted return to its source, and we know of no natural agent for its restoration. The slow and continued action of the *Guanœs*, then, by increasing the quantity of guano and diminishing to an equivalent amount the mass of nitrogen, must after a time modify the elementary constitution of the air.

Man alone restores to the atmosphere a part of the nitrogen it has lost by employing the guano for the improvement of his land, as he also restores to the animal and vegetable kingdom the carbonic acid long buried in the earth under mineral forms.

It is no longer worth while to contest the fact of the diminution of the aqueous mass of the globe. It is generally admitted that since the epoch of the first sedimentation, the sea has diminished to an amount equal to the mass of sedimentary rocks, minus the mass of the same rocks dehydrated. But the possibility of a continued diminution of the waters in the course of time is rejected, and for what reason? We know not, since the diminution of aqueous masses in the past is allowed. The nucleus of the globe constantly furnished mineral substances, which, by their disaggregation, their dissolution, and the evaporation of the

* D'Archiac, *Cours de Paléont. Strat.*, t. ii, p. 23.

† *Cours dePaléont. Strat.*, t. ii, p. 385.

dissolvant, pass into the crystalline state, and in this condition always contain what is called the water of crystallization. If the materials are not soluble, they form sedimentary beds, which retain the water in which they were deposited. Whoever has visited the quarries of hewn stone, and especially those of calcareous rocks, will be convinced of this fact; the freshly raised stones are soft and much easier to cut, as they have not lost their quarry-water. The aerolites also contribute to the absorption of water; the substances which constitute them, being inoxidized, absorb oxygen, and are afterward hydrated, forming deposits similar to those produced by bodies of terrestrial origin.

If the fluid envelope constantly diminishes, its action decreases in proportion, but with such extreme slowness that even after the lapse of several centuries there would be no apparent change in its condition. In the present state of our globe, we may say that nothing resists the slow and continued action of atmospheric forces. Everything is corroded and destroyed in the course of time by these powerful agents. It is their slow action which has hewn and fashioned the rocks of Swiss Saxony, whose singular forms and bold superpositions astonish the traveler. It is through their influence that the mountains are cleft with deep ravines, that the plains are furrowed by streams and rivers, which act as so many veins in this gigantic circulation where all proceeds from the sea and all returns to the sea.

The vapors which arise from the ocean through the influence of solar heat are, above the continents, condensed into rain, which, falling upon slopes of variable inclination, carries away in the streams formed all *debris* which, on account of the impulse of the waters, size or form, cannot resist the action of the water. When this *débris* reaches the rivers, it is there deposited in proportion as the rapidity of the waters diminishes, and fills up the beds of the rivers, which, in consequence, often change their course. Several rivers of Upper Italy, and especially the Po, have filled up their beds to such an extent that, in order to avoid the frequent floods which occur whenever the rivers are at their full height, it has been found necessary to raise the banks by means of dikes, an immense and almost interminable undertaking. Agriculture has, however, derived great advantages from this circumstance; for, as the water is higher than the surrounding country, it can easily be directed to all points where, for agricultural or other needs, it is required in great quantity. Fields of rice are thus inundated, gardens and fields supplied with moisture; in fact water is the nerve of the industrial and agricultural life of Lombardy, of Venice, and of the neighboring countries on the right shore of the Po; it is the source of the prosperity of the regions.

Toward the mouth of the rivers are deposited the finer materials, which have been retained in suspension in the water, and these form the sand-deposits which extend more and more into the sea, that is if the latter is tranquil, and if the action of the tides and waves is not too great; in the contrary case, these deposits, which are called deltas, on account of their form, are destroyed, carried far from the mouth, and deposited anew under the form of strata. The clay and sand likewise deposited acquire in time consistency, and mixed and cemented by means of soluble materials in the water are sometimes converted into hard rock. At other times, however, by the constant action of the waters, the sands are washed upon the low shores, where they are quickly dried and carried by the winds upon the continents. The hillocks or dunes which mark the progress of the sand invade many fertile countries, and threaten to convert them into arid deserts. The coasts of Guyenne (Lande) are an example; the sand-banks have there made great progress, although they increase at the rate of not more than two meters a year.

If the desert of Sahara was formed in this way, the sand-banks without doubt commenced at the western side of the African continent, where it still continues. But in order to reach from the Atlantic to the shores of the Nile (and it is not even two thousand years since this has taken place,) the moving sands must have taken more than two millions of years, and the distance which they have passed over is about 450 myriameters (2,800 miles).

The fluid envelope of the earth is not only affected by the sun; the moon also exercises an influence by its proximity in producing oceanic and atmospheric tides.* The tides of the fluid envelope, in general, are the product of the combined movement of the earth around its axis and around the center of gravity common to the moon and to the earth situated in the mass of the terrestrial globe. Before arriving at this explanation,† different theories were proposed, generally incapable of explaining the periodical return of the waters, when this could not be referred to the attraction of the moon.‡

The circulation of the fluids at the surface of the earth depends, as we see, upon the attraction of the moon and of the sun, and upon the radiant heat of the latter which produces the evaporation of the waters and their condensation in the form of rain, dew, hail, snow, &c. The influence of the nucleus of the earth is less and is manifested only by the changes produced in the interior of the crust and at the surface, consequent upon risings, eruptions, and earthquakes. The heat acts again upon the waters, which penetrate the crust of the earth, raising the temperature according to the depth. Hence the origin of many thermal springs. In order to explain the number of these springs, many scientists have generalized the action of the central heat upon the waters which penetrate the crust by fissures or by infiltration. They have thought that the waters are distilled by contact with the incandescent mass, and, deprived of all saltness, are condensed in the clefts of the rocks whence they gush out at the surface of the earth.

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* C. M. Elliott, *On the Lunar Atmospheric Tide at Singapore*, Phil. Trans. of the Roy. Soc. of London, 1852, 1st part, p. 125.

† Croll, *Phil. Mag.*, April, 1864, p. 287.

‡ Carus, *Briefe übcr das Erdenlebcn*, p. 153.

Mr. Nowak* has proposed a theory of the circulation of water, which, on account of its singularity deserves to be mentioned. It is based upon some observations made in the Andes by M. Boussingault. It admits the existence of an envelope of slight thickness which does not rest at all points upon the solid nucleus of the earth, but which is lifted up by the vapors proceeding from the waters which infiltrate it. The mountains then are only blisters raised by the force of the vapors which are there condensed. The pressure which these waters of condensation exercise upon the elevated parts of the mountain, produce in these blisters—to continue the simile—a species of running wound, origin of the springs, or by sudden action volcanic eruptions, disengagement of vapors, and the discharge of waters, as this phenomenon is manifested in the Andes.

It is entirely useless to look for the explanation of these springs in theories based upon problematical data; while observation demonstrates that the evaporation, the condensation of the vapors, and the circulation of the waters in the subterranean canals are sufficient to account for the formation of the springs. This is the opinion of Lyell, and he admits the influence of the central heat upon the production of these phenomena only in the case of thermal springs, the geysers, the mud volcanoes and other similar phenomena.

In this constant circulation the waters dissolve a part of the rocks through which they pass, and, impregnated with salts, return to the surface. Pliny observed that the waters are characterized by different properties, according to the nature of the soil through which they pass, and experience shows that, on account of the effect upon fruits and vegetables, mineral-spring water is unsuitable for culinary purposes, which is not the case with river-water. Instead of explaining this fact by antipathies and sympathies, as the heroic Romans did, chemistry teaches us that selenitic waters hold in solution carbonates of lime, which, in combining with the legumin, render these fruit unfit for alimentation.

An excess of carbonic acid facilitates the solution of a notable quantity of calcareous substance, which is deposited in proportion as the carbonic acid is withdrawn. In this way are formed, by the filtration of the waters charged with calcareous substance, the stalactites and the stalagmites of subterranean caves. M. Liebig explains in the following manner the formation of the stalactites. The vegetable materials in decomposition—or humus—under the influence of humidity and of the atmosphere disengage carbonic acid, which is dissolved in the rain-water. This water in traversing the pores of calcareous matter dissolves a part, and, in proportion as the excess of acid evaporates in the caverns, the calcareous material is deposited and forms the stalactites.†

The circulation of the fluids at the surface of the globe is, as we perceive, an essential condition of the organization of the terrestrial crust.

* *Die Lehre vom tellurischen Dampfe und von der Circulation des Wassers unserer Erde*, Prag, 1843.

† Lyell, *Antiquity of Man*, 1864, p. 74.

It has also prepared the way for organized beings; resembling life in its movement, it has rendered life possible, and without it life would cease. It was at first violent and irregular in action, but it prepared inorganic material for organization and animalization, and when the wild elements of nature were exhausted, at the mysterious mandate of creation, we see arise from the bosom of the ocean the first of those living beings which have taken possession of the earth and of the air.

The appearance and the development of life is a very important epoch in the history of the earth, and as such, as well as on account of the modifications of the crust occasioned by the existence of organisms, we will proceed to consider some important aspects of this phenomenon.

CHAPTER IV.

ORGANISMS.

It is an unusual circumstance, in penetrating the soil even to a slight depth, not to find organic remains. In examining these carefully and comparing them with living organisms differences are found so great that often they cannot be classed with any recent species or even genus. Sometimes there are entire families of which no analogues are found in the living creation, but which nevertheless, judging from the profusion of their fossil remains, must for a considerable time have dominated on account of their numbers and their form in the fauna or the flora of the period in which they existed. What is the reason of these successive appearances and disappearances? What laws control these perpetual changes? What are the causes which destroy a portion of these organisms and preserve others? These are the most difficult questions biology has to answer; let us see whether she can satisfy our legitimate curiosity.

Most of the sedimentary rocks are characterized by the presence of fossil remains, which are peculiar to them. We may say in the present state of science that the chain of organisms is continuous, commencing with the Laurentian formation. We find in the latter remains of microscopic animals, whose presence may be detected by chemical reagents.

The Silurian formation hitherto has relatively been the richest in organisms. We find in it mollusks and fish. If some of the genera of this formation have for a long time been extinct, others, especially among the mollusks, still exist; such are the genera *Nautilus*, *Turbo*, *Buccinum*, *Turritella*, *Terebratula*, &c. It is in this formation that for the first time we find the remains of plants; these are the fucoids which, as far as we know, are the first representatives of the vegetable kingdom.* These plants are perpetuated through all the periods, but always under richer and more varied forms. It is important to observe that

* Unger, *Chloris protogæa*, p. 8.

the primitive fucoids resemble more those of the tropical zone, while those of the late periods for the most part approach in characteristics the fucoids of the temperate zones, a fact which may serve as an indication in the determination of geological temperatures and climates.

From the appearance of these first organisms until that of man, life has been manifested under every imaginable form in the varied conditions of the different geological periods, for the biological evolutions have been affected by certain causes which act with increasing progression in immediate dependence upon the development of the earth's crust.

It is to *paleontology* we should apply for knowledge concerning the development and succession of the animals and plants of past ages. She employs the means placed at her disposal by geology and comparative anatomy to reveal in each period and in each formation a world whose strange forms have disappeared never to return. Each formation, however, does not represent an entire act of creation, but only a disconnected page from the scene of this great drama,* consequently the organic remains do not indicate to us the continuous succession of organisms, but rather certain periods of their development, certain episodes in the history of creation.

And what difficulties we encounter at every word in deciphering these pages. We require a Césalpin, a Leonardo de Vinci, a Palissy, and a Buffon to teach us their characters, and a Cuvier and an Owen to show us how to read them. How many prejudices had to be overcome before the learned men of the last century could be persuaded that these singular forms found in the earth were other than simple freaks of nature or the shells left by pilgrims upon the mountain-tops. The truth at last was brought to light and prevailed over the misconceptions of the world, but only very slowly were the facts obtained which allowed any certain knowledge of organic remains, and a deduction of the simple laws which control their development.

From analysis of these organisms and comparison of them with those that are recent, we find that their differences of structure are greater, in proportion as the strata which contain them are older; also that in the very ancient formations, the forms of high organiztion are more or less wanting in ratio to the age of the rocks. Thus the mammals in the Keuper (the upper division of the Triassic formation), the birds in the Mixed Sandstone, the reptiles in the Old Red Sandstone, the fish in the Upper Graywacke. We may therefore conclude that at a certain period there were no organisms whatever in existence. We might easily determine upon a certain period for the appearance of organisms, perhaps that of the complete precipitation of the waters, but at present it concerns us to know how they appeared, whether through the pre-existence of germs or by spontaneous generation. This is a question of very great importance, but concerning it we have still very little positive

*Darwin, *Geologische Aufeinanderfolge organischer Wesen*, Zeitschrift für die gesammten Naturwissenschaften, t. xvi, 1860, p. 428.

information. It is more discussed than any other in science, but as yet with no definite result.

Not only the origin of organized beings, but also their generic development is difficult to explain. Some savans believe in the transformation of species; others attribute to a direct creative force the continuous succession of new organic forms. We may say with G. Bronn* that we know of no natural force which can produce new species, and we do not know the conditions which are necessary for their production. We do not know any substance in which this force may be inherent; we know only that the individuals of a species already in existence are propagated by processes in accord with the simplicity or complication of their organization. According to Isidore Geoffroy Saint-Hilaire† the two hypotheses mentioned are equally inadmissible in the sense and to the extent they are ordinarily taken. They should not be entirely rejected, freed from serious errors which are mingled with great and fundamental truths. For instance, the fact given us by Professor Agassiz is very remarkable, that ancient animals resemble the embryos of the present existing animals of the same class, so that the geological succession of extinct forms is parallel to the embryonic development of recent animals.‡ The fact is undeniable, comparative anatomy has expressed itself positively upon this subject, but what conclusion can we draw from it? This, perhaps: that the superior animals are derived in a direct line from the animals whose forms are indicated by the various stages of development of the embryo, or, going further back to the egg, that the origin of all beings is in the infusoria. We do not place much value upon such conclusions, for although, according to M. Chevreul, the mutability of species is not an absurdity, to admit it as a fact, and to draw consequences from it, is to abandon the experimental system which does not permit us to use as a principle mere conjecture.§

The character of species has been equally a subject of controversy Certain physiologists base their determinations upon an indefinite fecundity, others upon a common origin and upon resemblance. The solution of these questions is not, however, absolutely indispensable for the study of the organisms which have successively occupied the surface of the globe, and for a sketch of the primitive world it is not necessary first to settle whether each species is the product of a direct creative force or the offspring of an extinct species. But it is essential to know that no new organism manifests itself until all the conditions of its existence are realized, which proves the influence of exterior circumstances upon the succession of organized beings.

The development of plants is more directly dependent upon the nature

* *Handbuch einer Geschichte der Natur*, t. ii, p. 653.

† *Histoire Nat. Génér. des Règnes Organ.*, t. i, p. 11.

‡ D'Archiac, *Cours de Paléont. Strat.*, t. ii, p. 97

§ *Journ. des Savants*, 1840, p. 715.

of the medium in which they live; and the great uniformity of their organization, with the limited number of their species, indicate an almost constant uniformity of exterior conditions. The ambient medium of the first organisms was incontestably water; and it is admitted that marine plants preceded those of the lagoons, and the latter the vegetation of fresh water. Terrestrial plants followed the aquatic, and are distinguished by a greater variety of forms. The *Equisetacea* represented to-day by the horse-tail or shave-grass and other analogous plants were the most generally distributed over the islands and continents of the first periods. They appear in all the sedimentary strata, from the most ancient to the most recent. The number of their fossil species known exceeds a hundred. The conformation of their stem permits their division into three categories, which mark the periods of development. The *Equisetacea* of the first period up to the Graywacke are arborescent calamites, whose longitudinal grooves continue in an unbroken line to the articulation of the branches. The second period, from the Coal epoch to the Mixed Sandstone, also contains arborescent calamites, but their grooves alternate with the articulations and the line of separation is broken in the form of a zigzag. Certain paleontologists explain why the sheath is wanting in the two forms preceding, while it is found with the *Equisetacea*, by supposing that in these two forms only the mold of the interior of the arborescent calamites has been preserved.

The *Lycopodacea*, also very ancient, hold a very important place, particularly in the Coal period. The arborescent kinds, such as *Lepidodrendon*, *Lycopodites*, *Knorria*, *Segenaria*, were giants compared with their humble representatives of the present day, of which the small number of species indicates a rapid decline. No other family of plants is found in the fossil state under so many forms or in such great number. Their exceptional preservation cannot be attributed to the ligneous and fibrous structure of their stem, but to their actual predominance in the flora of the Coal period.

The ferns commence with the Graywacke, and are already very abundant in the Old Red Sandstone. Their fossil remains are often so well preserved that the entire plant can be reconstructed with the greatest certainty, and its character studied as closely as with a living plant; for the most delicate parts, among others the organs of fructification, have well resisted the action of time, and they furnish very valuable data for phytotomy and the comparative organography of fossil and recent ferns.

Certain remains of fossil plants for a long time puzzled the paleontologists; now it is admitted that the *Asterophyllites*, the *Stigmariæ*, and the *Sigillariæ* are only roots and stems of the same species of vegetation, or at least of the same genus.

In the succession of the classes of the vegetable kingdom the *Monocotyledons* come after the *Acotyledons*. The number of their species increase up to the Chalk, and, in all, a hundred fossil species are known, thirty-seven of which belong to the family of the palms. The Cycads formerly so important, accompany the conifers, starting with the Coal formation, and attaining their maximum of development in the Keuper and in the Freestone, and diminishing in importance in the Chalk. The principal genera of this family are *Cycadites*, *Zamites*, *Pterophyllum*, *Nilsonia.*

The conifers, formerly always accompanied with palms, are now found from the warm regions of the equator to the inhospitable glacial zone. Their genera, *Pinites*, *Abietites*, *Araucaria*, *Voltzia*, *Juniperites*, *Cupressites*, *Thuites*, *Taxites*, and others, are still extensively distributed, and do not appear to have lost vitality.

The *Dycotyledons*, of which only a few traces are found in the last strata of the Secondary period, appear suddenly in the Tertiary period, and predominate in almost all the continents. These plants, with their large leaves, beautiful flowers, and succulent fruits, change entirely the aspect of the flora, while under the shadow of their great branches and in their thick foliage animal and vegetable life find shelter and protection.

In the animal as in the vegetable kingdom there is progressive improvement in the organization of the living creatures which have successively inhabited the terrestrial globe; but in general the importance of their fossil remains is inversely proportional to the development of this organization. Thus the *Infusoria** have left great beds, siliceous or cretaceous, almost entirely composed of their shells; and, in our day, in many parts of North Germany there are vast extents of country where, at a few yards from the surface, the damp soil is principally composed of living *Infusoria.* The city of Berlin is built upon such a soil. The *Polythalamia* and the *Foraminifera*, generally very small, are particularly abundant in the Chalk, which is almost entirely composed of them. The *Nummulites*, cemented by a clayish substance, form enormous deposits in the Upper Chalk.

The Polyps appear with the first sedimentary deposits of the transition period, but their principal genera quickly disappeared. Thus the genera *Catenipora*, *Syringipora*, hardly reached into the Carboniferous limestone. From that time until the Jurassic formation the genera *Gorgonia* and *Cythophyllum* prevailed. During this formation appeared the genera *Scyphia*, *Tragos*, *Achillum*, *Manon*, and *Astrea*, which are recent, while the *Cuemidies* rapidly disappeared. Until the Chalk period we find principally the *Syphonia;* the *Ventriculites* and the *Hippurites*, which are classed to-day, in spite of the authority of von Buch, with the bivalve mollusks belonging exclusively to the Chalk.

The *Crinoids*, under very elegant forms, are very numerous before the Chalk, but during the formation of the Cretaceous strata they disappear

* Many strata of microscopic fossils must be attributed, according to certain micrographs, not to the *Infusoria*, but rather to the *Diatomaca* and to the *Desmidia*, the siliceous carapaces of which were regarded by Ehrenberg as the remains of microscopic animals.

almost entirely. For a long time they were believed to be extinct. To-day, on the contrary, it has been proved that the sea of the Antilles contains representatives of this family. These are the *Pentacrinus caput medusæ* and the *Holopus rangii* of Martinique. (D'Archiac, op. cit., t. ii., p. 222.)

Australia presents us with a similar phenomenon. This continent not only possesses animals and plants which recall by their organization the fauna and flora of the Jurassic strata; but its shores still harbor mollusks which are found elsewhere only in the Lower Tertiary formations, and even in the more ancient strata. Subsequent to the *Crinoids* appear other echinoderms, particularly the free star-fishes, and the echinoids. The first are found in the Triassic formation, the last in the Jurassic. Several genera are still recent, such as *Cidaris*, *Echinus*, *Clypeaster*, *Ophiura*, and *Spatangus;* others have had relatively only a very short existence, as *Nucléolithes*, *Galerites*, and *Ananchytes*. The number of their fossil species is over a thousand.

The *Brachiopods* form the largest part of the fossil remains; they therefore render important assistance in the classification of the sedimentary deposits, and the determination of the relative age of these rocks. On account, however, of the especial knowledge required of malacology and of fossil remains, such means are of less general use.

In the most ancient formations predominate the genera *Spirifer*, *Ortis*, and *Productus*, which hardly attain the Triassic system, while the genus *Terebratula*, which appears simultaneously with the preceding in the micaschist of the Silurian period, passed through all the following epochs, and is also found in our seas. The other bivalve shells, especially, commence to increase in number with the Triassic formation; in more ancient strata they are relatively quite rare. In the shell limestone abound the genera *Avicula*, *Myophoria*, *Plagiostoma*, *Pecten;* the genera *Gryphæa*, *Lyriodon*, *Ostrea*, *Pholadomya*, in the Jurassic formation. The Chalk contains the genera *Exogyra*, *Inoceramus*, *Lima*, *Pinna*, and *Spondylus*, while the molasse (a soft Tertiary sandstone), and the deposits which follow, contain the genera *Arca*, *Dreissena*, *Panopea*, *Crassatella*, *Solen*, and *Pectunculus*.*

The fossil *Gasteropods*, of which the number of species is very great, are especially frequent in the molasse, but they are found equally in the more ancient deposits; the shell itself is very seldom found; only its imprint, or the mold of the interior, which renders the determination of genera and species very difficult.

The *Cephalopods* are of great importance in the history of the appearance of organized beings, and the part they played in past ages far exceeded that of the present. They form series which distinguish

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* Von Buch observed that the thickest portion of the shell does not occur in the same part with the *Brachiopods* of all ages. According as the shell belongs to the most ancient sedimentary rocks, to the mean or to the recent formations, the maximum of thickness is found near the ligature, in the middle, or toward the edge of the shell.

epochs and formations quite as well as the *Brachiopods*, or, among the plants, *Equisetacea*. The first series is composed of *Orthoceratites*, of *Belemnites*, and of *Sepias;* until the Zechstein, the *Orthoceratites* predominate, and after a long period appear in great numbers the *Belemnites*, which disappear in the Chalk, leaving no representatives, unless in the cuttle-fish and the sepia of our sea, of which fossil species are also found. The *Ammonites* form the second series, which commence with the Graywacke, and continue to the upper strata of the Chalk. The chambered *Cephalopods* are remarkable for the rapidity with which they developed into genera and species, and still more so for their quick disappearance after a renewal of the same forms in the *Baculites*, *Scaphites*, *Turrilites*, *Hamites.* It is a question whether with the sudden disappearance of the *Crinoids*, of the *Belemnites*, and a larger part of the *Saurians*, the conditions of animal life were not completely changed after the Jurassic period. The abrupt extinction of certain organisms is repeated quite often in the history of the sedimentary crust, and at intervals so regular that to attribute it to a fixed law, independent of all biological processes, is in accordance with all the facts furnished by contemporary geology, concerning the changes which have modified the surface of the globe. These fossil remains are a powerful auxiliary for the demonstration of this law.

The *Crustaceans* appear with the *Trilobites*, animals of a peculiar structure, which have no analogues among the Crustaceans now living. Their eyes, of complicated structure, are, according to Buckland,* the most ancient testimony of the existence of light. Other Crustaceans afterward appear, but have more analogy with those of the present time.

Insects are found in great numbers, distributed among the fossil plants of the Coal formation; later they are found in the Lignite or in yellow amber, which is the fossil gum of the *Pinnites succinifer*.

The large class of *Fishes* commence with the mica-schist. Professor Agassiz † divides the largest number of the fossil species into four orders, two of which, the *Ganoids* and the *Placoids*, continue from the mica-schist until our day, while the *Ctenoids* and the *Cycloids* are observed only since the Chalk. The fish of the primitive world were organized in accordance with the nature of the medium they inhabited. The most ancient were enveloped in a veritable armor of scales, which protected them from the violence of the elements. In course of time this envelope grew thinner, and at last disappeared.

The first traces of reptiles are found in the Zechstein, in the *Protosaurus*, which is not found in the following deposits. Some foot-prints found in the Old Red Sandstone have been attributed to saurians. In the Triassic formation we find the *Dracosaurus*, the *Notosaurus*, the *Phytosaurus;* in the Jurassic formation, the *Ichthyosaurus*, the *Plesiosaurus*, the *Teleosaurus*, and other species not less strange in form and proportion;

* Pouchet, *L'Univers*, note 94, p. 420.

† *Researches upon Fossil Fish*, t. i., pp. 165, 172.

in the Chalk, the gigantic *Mosasaurus*, the *Iguanodon*, and the *Hyleosaurus;* all these animals after a period of great importance gradually diminish and disappear in the Chalk. Up to that time the saurians ruled as sovereigns over land and sea to the sixty-fifth degree of latitude. Even the air was invaded by fantastic pterodactyles, with wings, claws, and crocodile's head, and lacking only the proportions of the dragons with which the imagination of poets peopled the grottoes and caverns in times past. Everywhere hideous creatures crawled or slept in the sunlight, and preyed upon each other when, after a long season of repose, hunger or other needs forced them to activity. Their voracity was such that they did not spare even the individuals of their own species. This fact is proved by the analysis of the *coprolites*, whose discovery is due to Miss Mary Anning. The rivers, lakes, marshes, and shores all were filled with monsters, whose scale-covered bodies glistened in the sun's rays, while in the damp forests, hidden among the branches of the virginal crowns of the palms, other reptiles lay in wait for their prey. The appearance of the crocodile is the last act of this exuberant creation, whose forms cannot fail to astonish us when in thought we compare them with the creatures of the present world; and this is our only link with this class of animals, which, within a time relatively limited, had very extended ramifications.

The *Chelonians*, the *Batrachians*, and even the *Ophidians*, were, according to Owen, very numerous and well developed in the Jurassic and Cretaceous periods, although Cuvier concluded from the few fossil remains of serpents found that they were rare at the times mentioned.*

The fossil remains of *Birds* are found particularly in the red sandstone of Massachusetts, which corresponds very nearly with the mixed sandstone of Central Europe. Foot-prints especially are frequently discovered. In later deposits new species appear, and fossil remains become more frequent.

The *Mammals* commence with the marsupials. In the schists of Stonefield, belonging to the Jurassic formation of England, we find incontestable remains of these animals, which, by their organization, form the intermediate link between the oviparous and viviparous animals. The *Cetaceans* were developed at the same time, and attained colossal proportions. Among the animals of dry land were the *Pachyderms*, beginning with the herbivorous, which first attained great development. These animals were the initial efforts of nature, which by these inert forms prepared the way for other animals, whose light and graceful structure was better suited for pursuit or flight, for attack, and for defense. The *Paleotheria*, the *Anoplotheria*, the *Chœropotami*, the *Adapides*, the *Xyphodonts*, were the principal animals living at this time. The immense forests and vast plains furnished them with an abundant supply of food.

* Cuvier, *Recherches sur les Ossements Fossiles*, t. v, 2d part, p. 526.

Among all the fossil mammals none more excite the interest of scientific men and the curiosity of the public than the mammoth. Its great height of from twelve to fifteen feet, the size of its tusks, its trunk, give it a sort of family likeness to the elephant; however, its thick reddish hair, the remains of pine branches found in its stomach, the discovery of a mammoth, preserved entire in the ice of Siberia, denote that it was not an inhabitant of the tropics like its congener, the elephant, but of the temperate and cold zones of Central Asia and of America.

A species nearly allied to the preceding, the mastodon, formed in its cosmopolitism an exception to the continental localization not only of the living animals, but also of the fossil mammals of the Pliocene and Post-Pliocene formations. The mastodon is represented by species differing very little in Asia, in the two Americas, and even in Australia; and what is worthy of remark, it is the only quadruped that lived upon the latter continent which was at the same time represented by analogous species in some other part of the world.*

The ruminants occupy the second place in the succession of the herbivores. Magnificent stags with enormous horns, fallow-deer, elks, gazelles, reindeer, and other known species, browsed together upon the same vast plains, while to-day these species are distributed over every zone and throughout all parts of the world. These inoffensive creatures, which with other Herbivores occupied almost exclusively the surface of the globe, were soon obliged to defend themselves from the attacks of the carnivorous animals, which lay in wait for them in the forests, and pursued them in the open plains. In proportion as we approach the upper strata of the sedimentary crust, the number of the Carnivores increases rapidly; for beside the large dogs, nearly five feet high, which were probably the first to appear, we find representatives of the cat family, of the plantigrades, and of the wolves. The bone-caves, excavated for the most part by the action of the sea, are filled with the remains of the bones of a great number of animals, and, as has been stated, in some cases, with the imprint of the teeth of Carnivores upon them, it is thought of the animals which carried these bones into the caves.

If we attentively examine the development of organized beings, and compare it with the stratigraphic development of the earth's crust, we find that there is a certain parallelism which can be traced throughout all the geological periods. When the crust of the globe was only a thick sediment without apparent stratification, resting upon the cooled lava, what living creatures inhabited the earth? Some *Infusoria* hardly more complicated in structure than snow crystals or other mineral concretions, whose individuality was constituted as much of silica as of carbon. In our time we would say almost that the richness of strata is in proportion to the richness of animal life. Asia, extremely well developed in a stratigraphic and orographic point of view, is also the only

* Owen, *Report on the Extinct Mammals of Australia*, London, 1845, p. 20.

continent which appears to unite all the conditions required to be the seat of the creation of man; while Australia, poor in strata, is equally poor in its organisms, which all appear to be the remnants of past ages.

Everything in nature is intimately connected; the mineral kingdom is a condition of the vegetable, and the vegetable of the animal. And even within the animal kingdom there are creatures whose existence involves as a condition the destruction of other animals. Plants cannot exist for a long time alone upon the surface of the globe; for finding no limit to their growth and extension, and not giving back to the atmosphere the carbon they are obliged to draw from it, the latter element would in time be exhausted and they would perish. But nature has created the herbivores who, in consuming and digesting the alimentary plants, hasten in the first place their decomposition, which takes place slowly only under the action of the air, and besides restore to the latter by respiration the carbonic acid indispensable to the vegetable kingdom. The herbivores, in their turn, would compromise their existence by destroying the plants which serve them as food, if nature had not imposed limits upon their multiplication by creating for them implacable and sanguinary enemies.

We have already examined in what manner the vegetable kingdom, seat of the cosmic forces, is in relation to the activity of these forces, which have modified the surface of the globe; it remains to be seen in what way the appearance of animals and vegetation influences the organization of the terrestrial crust.

Plants are, Oken* observes, organisms suspended between the earth and the sun, or, if you will, between darkness and light, whose appearance has as a condition the influence of the central luminary of our planetary system upon the earth. In fact, without light, plants fade and die, while in the ardent rays of a tropical sun and under the influence of the humidity of these warm regions, favorable to them but fatal to the human race, they develop those beautiful forms and brilliant colors which constitute the ornament of equatorial regions.

Some savans have supposed that the aurora borealis may at some period have supplied the place of solar light, and in consequence the growth of plants have extended over all parts of the globe. It is probable that the chemical activity of the earth, indubitably greater at the periods when organisms were produced, gave more importance to this electro-magnetic phenomenon; but notwithstanding this probability, we dare not affirm its influence upon organisms, not knowing the time of the appearance of organized beings, nor the period when the rupture of the cloudy envelope dissipated the darkness which covered the earth. Whatever may have been the source of light, we see that the conditions of existence must have been very uniform, since the same fossil-remains are found at the equator as in the polar regions. The submarine forests of the shores of Greenland, and the coal-beds of the islands of Disco

* Tr. Bromme, *Atlas zu Al. v. Humboldt's Kosmos*, p. 106.

and Spitzbergen, regions now permanently covered with ice, are evidence of a uniform climate very favorable to the increase of vegetation. For a long time it was matter of discussion how trees could flourish and form forests so near the pole, since the solar light failed them during a large part of the year, and the heat was insufficient. It is, however, not difficult to conceive that plants do not require light when, through extreme cold, which deprives them of their leaves, they go to sleep, so to say, in order to await the return of light and heat. It would be only necessary for their preservation that the cold to which they were exposed was not too extreme.* Now the heat which mitigates the rigor of the climate is furnished by the oceanic currents, proceeding from the equatorial regions.

According to Humboldt, currents depend upon the tides in their movement around the globe, upon the duration and force of dominant winds, upon the difference of the specific gravity of the waters or their degree of saltness, and finally upon the horary variations of the barometric pressure. Now, all these causes which influence the production of ocean currents are variable. The movement of the tides is modified by the configuration of the continents; the winds by the unequal distribution of the land and water, the very different calorific capacity of which produces ascending currents, the real generators of aerial currents. The difference in saltness is produced by the great quantity of fresh water which is emptied into the ocean, or by the abundance of the rain, very variable upon the sea. The result is that the currents themselves are variable; and if to-day the western coasts of Europe are visited by the Gulf Stream, in former times this current may have been directed more to the north, and promoted upon the American islands and upon Spitzbergen the development of vegetation. The cold currents, on the contrary, may have proceeded along the European coasts and produced there a climate similar to that of Canada and Labrador.

The climatic conditions may also be changed by the predominant distributions of the sea upon a hemisphere, and in this case a damp and foggy climate would be the consequence. Now, such a climate, even were it quite cold, would not prevent the development of a rich cryptogamic vegetation, as is shown by the flora of the islands of Falkland and of New Zealand. There is nothing, then, averse to the supposition that, at certain geological epochs, the climatic conditions were very favorable to the development of plants, and that their growth was possible even in the polar regions. Moreover, the coal-beds of the islands of Disco and Spitzbergen cannot be the result of the accumulation of floating wood, for, in the first place, the *débris* thus deposited would be mingled with sand and pebbles, and, in the second, trunks of trees still standing have been found in these beds.

Plants act a very important part in the economy of nature. They are the immediate agents of organization, and serve as intermediates

* J. Croll, *On Geological Time, etc.*, Philos. Magaz., vol. xxxv, 1868, p. 445.

between the mineral and animal kingdoms, the latter not assimilating directly inorganic substances. Plants decompose the carbonic acid of the air, under the influence of solar light, and set free the pure oxygen, which is necessary for the respiration of animals; also, they absorb the inorganic salts and form albuminous azotic substances, which are engaged in the production of the horny cartilaginous or bony frames and the formation of the tissues of the animals. The humus is the production of the slow alteration of plants mingled with mineral substances. It is found in a fossil state in all the deposits, and serves to promote the development of plants to a more perfect organization. Upon an arid rock first appear the lichens, which by their decay form enough earth to allow the mosses to succeed them; the grasses, finding the necessary conditions for their development, follow the mosses, after which any of the plants may dispute the new ground acquired for their nutrition. The same succession takes place on a large scale in the organization of the terrestrial crust.

The preservation of the fossil remains of primitive plants is due to certain agents which prevent their decomposition. Water, for example, destroys certain parts of a plant, while others are preserved in it for quite a long time. The preservation of the soft and tender portions indicate that these plants were soon covered with lime, and that they were not deposited far from the place of their growth.*

Some streams preserve their plants by depositing rapidly upon their entire surface a stratum of calcareous matter which, gradually increasing in thickness, shields them from all exterior action. To this process we are indebted for the elements of a quite new science, paleophytology, which in many cases has opened the road to the discovery of the general laws which have controlled the modification of climates.

Plants are not only found scattered here and there through the sedimentary strata; their remains frequently form large deposits, such as the beds of coal, lignite, and peat. In former times the products of the decomposition of these deposits, such as bitumen and petroleum, were found in such abundance, that their exploitation equaled in importance that of coal, which, with iron, forms the basis of great industrial wealth.

Coal is quite abundant in Europe; England, Belgium, France, Prussia, Silesia, Bohemia, Hungary, possess mines of more or less importance. Scandinavia, Russia, Greece, Italy, have, we may say, no coal-deposits. Of other parts of the world, America is the most richly gifted, while Australia possesses the least.

The value of all the coal-deposits has been calculated by the Prussian engineer, Mr. Carmel. He compares the whole amount to a solid mass of 44,800,000,000 cubic meters (58,000,000,000 cubic yards). He at the same time allays the apprehensions often expressed that this precious combustible will be exhausted by its enormous consumption, which annually draws from the earth a hundred and twenty-five million tons. This

* F. Unger, *Chloris protogæa*, 1847, p. iv.

would give a stratum two meters in thickness (6½ feet) and 56 square kilometers (21 square miles) of extent. As the volume of the coal-deposits is known, as well as the annual quantity consumed, it is calculated that this store of combustible material will not be exhausted for thirty-six thousand years.

The formation of coal is not easy to explain. Are these deposits collected in the hollow of valleys, at the bottom of lakes, at the mouths of rivers or in turf-bogs? Modern research inclines toward the latter supposition. The nature of the plants the *débris* of which forms coal implies the presence of marshes, on the borders of which these plants grew; if such was the case, coal is a formation analogous to peat. The climate must have been damp and temperate as in our day. The trees which bordered the swamp fell into it as they were uprooted by the violence of the winds, and thus increased the quantity of vegetable matter which formed the coal. For a long time the carbonization of the remains of plants was attributed to the influence of terrestrial heat; but Gœppert has shown that it is rather due to the enormous pressure and the action of chemical agents, which produced a peculiar decomposition, the consequence of which was the metamorphosis of wood into coal. A piece of *Pinnites succinifer* transformed into black coal, while some amber adhering to it underwent no alteration, is a proof in favor of this view, for otherwise the co-existence of the coal and the amber would be altogether inexplicable.

Some geologists consider that anthracite is a deposit of vegetable matter, which preceded the formation of [bituminous] coal. But in 1831 Featherstonehaugh showed that the anthracites and [bituminous] coals were deposits formed at the same time, and were often contained in the same stratum. The identity of fossil plants in the two substances proves the same thing.* The chemical difference of the two combustibles must, then, be attributed to stronger pressure, to the presence of more energetic chemical agents, and in every case to a greater degree of terrestrial heat.

The lignite deposits are collections of vegetable matter, encountered in more recent formations. The thickness of these strata rarely exceeds 5 meters (16½ feet). It is a combustible not much sought after, for when it comes out of the mine it contains as much as 45 per cent. of water, which is disengaged with difficulty, by exposure to the air. It contains only about 50 per cent. of coal, and its calorific power varies between six and eight thousand *calories*. It is found in the secondary and lower strata of the Tertiary deposit. Its quality diminishes in proportion as it exists in more remote periods.

The formation of deposits similar to the lignite is taking place to-day in the neighborhood of the mouths of large rivers. We may give as example the large quantity of wood floating in the Mississippi, forming often regular moving islands of matter. A portion of these vegetable

* Lyell, *Travels in North America*, vol. 1, p. 88.

débris is cast upon the banks at the mouth of the river, is covered with mud and penetrated with saline matter, while a large part is carried far away by the current, and furnishes valuable building material to the inhabitants of the glacial zone.

The bitumens, the petroleums, and the naphthas are hydrocarburets, more or less condensed, which proceed from the decomposition of large deposits of vegetable matter, imprisoned between the sedimentary strata, and submitted to variable pressure. Such is the conclusion we have attained, thanks to the researches of synthetic chemistry, which teaches us that the products of the distillation of wood can, under certain conditions of temperature and of pressure, be transformed into more complicated carburets.

Petroleum is largely diffused in the terrestrial crust. In Europe, and especially in Gallicia, several pits have recently been discovered. Asia is quite rich in this product, but in North America it has become the object of a very important and extended industry. The tubes bored for the purpose of obtaining this oil pass ordinarily through the ferruginous clay, the sandstone, the conglomerate, and the bituminous schists before reaching the bed of oil confined between two strata of refractory slate, containing the fossil remains of *Stigmaria* and other plants of the Coal period. When the drill reaches the bed of oil, a regular explosion of gas takes place, the latter consisting in most cases of a mixture of carbonic acid and hydrocarburets. This explosion is followed by a continuous jet of oil, which shoots up sometimes to a height of more than 30 yards. Both gas and oil being eminently inflammable, many disasters occur in boring the petroleum-wells. The yield from these pits is sometimes as much as 4,000 gallons of oil in twenty-four hours. The daily product of all the wells of the United States may be estimated at 50,000 gallons. The oil is generally of a deep-brown color, and only in a few cases is clear and transparent. A simple distillation suffices to render it fit for ordinary use.*

We may consider as an organic product the gas disengaged in several parts of Italy and in Transylvania, and now burning at Bakou, on the Caspian Sea. The Ho-tsing or wells of fire in Central Asia, of which Humboldt has left a very detailed description, are equally gaseous emanations, proceeding from the subterranean decomposition of vegetable substances.

Peat is a recent deposit of vegetable matter, the formation of which appears to have some analogy with that of oil. The remains of all kinds of plants may contribute to the increase of peat-bogs, but in order that marshes become peat-bogs certain conditions are necessary favoring the development of the plants of which the largest part of them are formed. Thus the water must not be completely stagnant, must not be impregnated with slime nor be liable to any great rise or fall, must not be very deep and not rapid in motion, while the bed of the marsh

*A. Gesner, *Quart. Journ. Geolog. Soc. London*, t. xviii, p. 3.

should be argillaceous and impermeable, but never sandy nor gravelly.* Peat is principally composed of the ligneous and fibrous parts of the *Carex eriophorum*, and certain mosses, whose decomposition has been retarded by the circumstance that the temperature of the water in which they were, never passed beyond a certain mean, and also by the presence of some organic acids. The depth of peat-bogs is often very great, sometimes as much as 18 yards. Their lateral extent is seldom over 3 yards, ordinarily not more than 1.

M. Lesquereux has made upon the subject of the geographical distribution of peat-bogs, some very important remarks. He observed that the peat-bogs of Europe extended between the forty-fifth or the forty-sixth degree of north latitude and the regions where the growth of ligneous plants ceases. A corresponding limitation is given for their vertical extension; in the Alps, for example, they are contained in the valleys up to a height of 2,600 meters (8,500 feet). According to Mr. Darwin, there is no peat in the island Chiloe at 41° to 42° of south latitude, notwithstanding the great number of its marshes; on the contrary it is very abundant in the Chonos Islands in 45° latitude. The temperature favorable to the development of peat-bogs is an annual mean of 5° to 8° C.; the development ceases when the temperature attains 10°. M. Lesquereux concludes from this that the temperature of the globe has not sensibly changed since the Quaternary period, for if during this period the temperature of Scotland had fallen to that of the Azores, we would find somewhere in the south of Europe deposits contemporary with this cooling, which is not the case. M. d'Archiac however, considered that this supposed decrease of temperature is not incompatible with the absence of peat, for he thinks that this low degree of heat may have continued for too short a time to produce great deposits; or, if these were formed, they may have been carried away by the diluvian action which denuded this zone.† As to the age of the recent peat-bogs, there is but one opinion, that their formation commenced with the cessation of the last diluvian phenomena.

Animals, more than plants, contribute to the formation of permanent crusts at the surface of the globe; especially the inferior animals, the *Crustacea*, the *Mollusca*, *Cephalopoda*, *Gasteropoda*, *Acephala*, *Brachyopoda*, the *Radiata*, *Echini*, *Crinoidea*, *Asterioida*, the *Polyps*, the *Foraminifera*, and the *Infusoria*, which are born, live, die, and are buried in the same place, upon the same bank, at the foot of the same rock, and which form thick strata, consisting entirely of their calcareous remains. The residue of the terrestrial animals is less abundant, because their remains are generally disorganized by the influence of atmospheric agents before they are carried into the sea. Still, the tusks of the mammoth found in the ice of Siberia, the bones discovered in the caverns, the guano of the Chincha Islands of Peru, of the coast of Chili, and of Terra del Fuego,

*D'Archiac, *Cours de Paléont. Strat.*, t. ii, p. 390.

†D'Archiac, *op. cit.*, t. ii, p. 397.

and the atmospheric dust, composed in great part of infusorial remains, form materials which add to the deposits of inorganic substances.

The strength or durability of strata formed of the remains of marine animals depends upon certain exterior conditions which are very variable. Thus, the *structure of their sides*, their petrific character, and their contour, more or less broken; *the nature of the bottom of the sea*, which may be muddy, sandy, gravelly, and filled with broken shells and corals; *the tides*, the difference between the high and low water; *oceanic currents*, transporting the germs to a distance; *climate; the composition of the waters*, their degree of saltness, and particularly *their depth*, all contribute to complicate the character of a marine fauna, and determine, more or less, the abundance and the variety of forms of a particular region.* E. Forbes has established certain laws upon the relation which exists between the bathymetrical and geographical extension of the marine animals. He has shown that the extension of a species in a vertical direction corresponds to its horizontal or geographical distribution, and, conversely, that the more a species extends in a vertical direction, or, in other words, the more it is found at different depths upon the same coast, the more it is diffused over large surfaces.

The *Mollusca* rarely live at a depth of more than five hundred yards. Now, for animals which can live only a hundred yards below the surface of the water, all depth beyond this is an insurmountable obstacle to their extension. This fact may explain why on two sides of a cape are often found two almost completely distinct faunas. It has also been observed that northern species, on approaching the equator, seek a depth of water where the temperature is equal to that from which they came. The reverse takes place with tropical species. The result is that the geographical extent of a species must be greater in proportion as it can live at a greater depth. As the molluscal animals do not repeat themselves on the two sides of the equator, although the type may be the same, it must be admitted that the equator is equally an obstacle to the distribution of the *Mollusca.*†

A change in the saltness of the water is also an obstacle to the existence of marine types. In the lagunes and salt marshes near the mouths of rivers, *Mollusca* are found, indicating by their presence every degree of saltness, from sea-water to fresh. If the degree of saltness is changed, the primitive types are replaced by others better adapted to the medium. It has been often asked whether an acclimatation of the marine types is not possible in a medium where the change in the saltness takes place very slowly. We may answer in the affirmative if we consider the acclimatation of the *Phoca* of Lake Baikal which formerly was a part of a vast sea, and also if we take into account the persistence of the lower animals which have endured through all ages, and still form the most numerous inhabitants of our globe, while the existence of the superior

* D'Archiac, *op. cit.*, t. ii, pp. 190–194.

† D'Archiac, *op. cit.*, t. ii, p. 226.

animals is so limited that they are born and perish in a period which for the *Testacea* is recent.*

The least complicated seem best to resist the changes of condition due to the influence of the revolutions of the terrestrial crust; those which through simplicity of elementary constitution approach nearest the mineral kingdom share somewhat its resistance to the agents of destruction.

The presence of the fossil remains of marine animals in the interior of continents proves that the configuration of the latter is not invariable. We have already spoken of the slow rising of Australia. Central Asia, also, must be the elevated bed of a former ocean, for Kirghiz and China show that there must have been an interior sea where now exists the desert of Gobi.† Besides, deposits of shells have been observed at elevations of from three to four hundred yards, and even higher.‡ The levels of erosion of the Alps, observed by Sharp at heights of 9,000, 7,500, and 4,800 feet, prove that the level of the sea has changed several times.§ In former periods England was united to the continent, as is evident from the similarity of the molluscal fauna of the British Isles with that of the continent, and from certain geological considerations in regard to the fauna of the Quaternary *Mammalia*. Thus we know of no species of fluvial *Testacea* in England which is not found upon the continent, while several species of recent appearance on the continent are wanting in England. If the Azores and the Canaries possess species peculiar to them, this proves that by their isolation these islands have become centers of distinct creations, which is not the case with the British Islands, on account of their dependence upon the continent.

M. Laurent, in charge of the formation of artesian wells in the northern part of Sahara, asserts in his report that the desert was once a sea, communicating through the gulf of Gabes with the ocean. Among the fossils discovered, one, the *Cardium edule*, is frequently found in the Mediterranean, and still lives in the salt lakes of the desert.

The existing continental fauna of Morocco, and of Algeria as far as Bacca, is almost identical with the fauna of Southern Europe. Only from the Senegal to the Nile commences the fauna of true African character. The elephant, the rhinoceros, the hippopotamus, the giraffe, the crocodile are not found beyond the desert, and the continental fauna of Africa coincides closely with that of Morocco, while the latter has much analogy with the European fauna. The *Innuus ecaudatus* is found upon the rocks of Gibraltar. The *Sorex etruscus* of Italy re-appears in Algeria. Strauch shows the identity of the reptiles of the two coasts, and Ericson affirms that a large number of insects of Central Europe and a still greater number of the Mediterranean countries are the same as those of Morocco and of Algeria, while there are very few species identical with

* Lyell, *Elements of Geology*, trad. Gineston, t. i, p. 213.

† Humboldt, *Asie Central*, t. ii, p. 138.

‡ D'Archiac, *Histoire des Progrès de la Géologie*, t. ii, p. 302.

§ *Quart. Journ. Geolog. Soc.*, 1855, t. xii, 46, pp. 102–123.

those of Egypt. If we also take into account the fossil remains found in the bone-caves of Sicily, we must admit, with M. Anca, that Europe was connected with the African continent by two isthmuses; the one represented by the present submerged plateau, which extends from the southern point of Sicily to Africa; the other, easier to determine, is the isthmus of the columns of Hercules, which united Morocco with Spain.

All these facts show us the dependence which exists between the organic and inorganic world. If the exterior conditions influence the development and the distribution of plants and of animals, on the other hand animals and plants modify the structure of the sedimentary rocks, by depositing upon them their organized remains. But in general we may say that the end toward which all the forces of nature tend is found in organization of matter, and consequently the crowning act is the formation of living creatures, animals endowed with sensation, and lastly of man, the final expression of the creative force of the earth.

CHAPTER V.

ICE.

From the appearance of the first organisms until our time, the earth has experienced every degree in the climatic scale, from the warm and uniform to the rigor of later periods. Besides this slow cooling, it is evident there were oscillations of temperature, from the periodic increase and decrease in the extension of certain plants of the temperate regions.* We still find, even in our day, in different parts of the globe, changes of climate, the cause of which is far from evident. M. Charles Zenger concludes, from his numerous observations, that the annual heat of central Europe sensibly increases, but is not able to attribute this change to any known cause.† His observations coincide with the appearance of meridional plants in the north of Germany, noticed in 1835–1836. We may, on the contrary, attribute to a slow cooling the increased extent of the Swiss glaciers, which, from the twelfth century, have more and more obstructed the ancient passes of the mountains, destroying forests and habitations and reducing the temperature of the surrounding country. In France and Belgium, the culture of the vine has ceased in many regions, where formerly its products were of great importance. The disappearance of pines in Ireland indicates that Great Britain also experiences this decrease of temperature. But the most striking proof of a considerable cooling is furnished us by the dwindling and decay of the birch forests of Iceland. This island, eminently volcanic, was, in the middle ages, the seat of an advanced civilization. The arts and sciences flourished there, and its poetry still astonishes the reader by its

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* Count Gast. de Sporta, *Annals and Magaz. of Natural History*, 3d ser., vol. xix, 1867, p. 351.

† *Phil. Magaz.*, June, 1868, p. 433.

freshness and vivacity. But then, as numerous documents testify, all nature contributed to enlarge the ideas and excite the imagination of the poet. The magnificent woods were peopled with numerous animals, and the nightingale made music in the groves of this island now ravaged by cold and fire. Spitzbergen, formerly accessible, is now completely surrounded by ice. Greenland, once a flourishing colony, founded in 982 by the Norwegians, commenced to decline about 1348, and this verdant country, which, according to a list found in Rome, had already, anterior to the fourteenth century, seventeen bishops, and numerous relations with Iceland and Norway, had to be discovered anew in the sixteenth century. To-day it is completely covered with ice, and its eastern side is altogether uninhabitable.*

It is also a well known fact that the passage between the Pacific and the Atlantic oceans, by the polar sea, is becoming more and more impracticable and even impossible, on account of the ice which obstructs the straits and canals.

We cannot say with Boussingault that to an elevation of the mountain-chain of the Andes must be attributed the retreat of the line of perpetual snow, for a change of climatic conditions in the general direction of the winds, and the quantity of atmospheric precipitations takes place more readily in certain regions, and may consequently modify the climate.

If we pass from the local to the general distribution of climates over the globe we are struck with the unequal division of heat in the two hemispheres. The borders of the southern glacier attain, and sometimes pass beyond, the seventy-fifth parallel, while the northern glacier reaches very nearly the eightieth parallel. Travelers who have wintered on the borders of the southern glacier have shown us, by means of thermometric tables, that the mean temperature is hardly higher than that of northern latitudes very near the pole, in which some vessels have been forced to remain during the winter season. Dumont d'Urville affirms that the floating islands of ice frequently encountered in the southern sea are of a size unknown among the icebergs of the northern hemisphere. Their length exceeds sometimes 20 kilometers (12½ miles), and their height 30 meters (98 feet). This enormous mass represents moreover only that part of the ice which is above the surface of the water, and is only an eighth of the entire amount.†

Geological periods also give us proof of numerous oscillations of temperature. In fact, after the Carboniferous period, so rich in vegetable forms, we observe a relaxation and very marked diminution in the evolution of animal and vegetable life during the Permian period and also during a part of the Triassic period.‡ It is in the Permian deposit that

* H. G. Bronn, *Handbuch einer Geschichte der Natur*, t. i, p 131. Alph. Favre, *Recherches géologiques*, t. i, p. 178, note 1.

† Lyell, *Travels in North America*, 1845, vol. II, p. 100.

‡ D'Archiac, *Cours de Paléont. Strat.*, t. ii, p. 11.

we find for the first time numerous scratches whose origin, much discussed, has been recently attributed to the action of ice. A similar and very pronounced arrest of vegetation is manifest after the Jurassic formation, in the Cretaceous deposit, and at several epochs during the Tertiary period, which is especially demonstrated by the predominance in Europe now of tropical, now of hyperborean types. A striking example of a notable change of climate is given by E. Forbes. This savan has registered a list of fifty species of shell-fish which inhabited the British seas at the time of the formation of the coralline crag and of the red crag (of the Pliocene). All these mollusks are recent, but they are completely wanting in the Pleistocene or glacial deposits of England. We find them in those of Sicily, of Southern Italy, and of the Grecian archipelago. E. Forbes thinks that these mollusks resorted for a time to these shores, where they found conditions favorable to their existence, and after the amelioration of the climate returned to the British seas.*

Mr. Heer has drawn attention to the fact that we find in many localities of France and of Germany bones of the marmot and of the reindeer, which can only be accounted for by a lowering of the temperature of Central Europe, which permitted these animals to live in latitudes less elevated and at a less vertical height. M. Lartet has mentioned in a letter addressed to the Academy of Sciences the presence of the *Ovibus moschatus* in several localities in the ancient province of Perigord. In the Quaternary then it must have lived 15° farther south, for at the present period it first existed only in North America and never passed beyond the sixtieth degree. M. Alph. Milne Edwards found in the bone-caves, among the animal remains, portions of the large owl (*Stryx nyctea*) which to-day inhabits the polar regions.†

The glaciers, whose growing proportions we have mentioned, were once much more extensive than they now are, as the moraines prove we find in Piedmont and Lombardy, upon the Jura, and upon many other mountain chains, where now no glaciers exist. We find these moraines in the Vosges, in the Black Forest, in the mountains of Scotland, upon the Apennines, Mount Libanus, the Alleghanies in Northern America, in New Grenada, and in New Zealand.‡ It is well known that the glaciers move along the sides of the mountain more or less rapidly in proportion to the slope. They would end then by overflowing the entire valley if the melting of their extremities did not keep them at a certain height. It is only after a series of exceptionally cold years that any progress can be perceived in the glaciers, while only a few very warm years suffice to produce a very sensible retreat. Now, if in former times the glaciers extended to the environs of Turin, this would prove that this extension was due entirely to a period of severe win-

* Lyell, *Elements of Geology*, 6th edit., t. i, p. 330.

† Favre, *Rech. Géol.*, t. 1, p. 182–183.

‡ Ibid., p. 181.

ters. How much must the mean temperature of Europe be lowered in order that the extension of the glaciers attain such proportions? The estimation is not difficult. In the first place, experiment shows that the temperature diminishes one degree for 188 meters (616½ feet) of height. The glaciers descend 1,150 meters (3,772 feet). The mean temperature must then be lowered 6° or 7° centigrade in order that the glaciers may descend to the level of the sea. This is actually the case in the island of Georgia and in Patagonia, where, according to Darwin, the glacier reaches the level of the sea at 46° 40′ of south latitude.* According to M. Ch. Martin, a lowering of 4° centigrade would be necessary in the mean temperature of Switzerland in order that the glaciers of the valley of Chamounix should extend to the environs of Geneva.†

Another proof of the action of ice is given by the abraded and polished rocks. The glaciers scratch the rocks in the bed of their course with the pebbles and stones contained in their lower strata; they polish the salient points they encounter first by their passage around them, and afterwards as their mass increases by their movement over them.‡ This phenomenon is not only observed in Switzerland, but also in Sweden, in Norway, in Lapland, and in Finland. In the latter province, the striped and polished surfaces are especially remarkable, because the country is not mountainous; now the phenomenon in this case can only be produced by the action of permanent glaciers, which would imply a considerable cooling of the mean temperature of Europe. It is true that the scratches and polish upon the rocks has been attributed to the action of floating icebergs, which plowed the bottom of the sea with the stones attached to their lower surfaces. This opinion is difficult to sustain, in view of the, for the most part, parallel character of the stripes in Finland, and the direction almost always north and south of the stripes. If floating ice had produced these marks, the scratches would not have been parallel, nor in the same direction; for, supposing the current constant in its course, the rotation of the floating mass should be taken into account, and also the obstacles the current would meet, causing it to deviate, and producing whirls and rapids. Moreover, Greenland, which, at an equal latitude, is now permanently covered with ice, shows the possibility of a similar cooling in Southern Europe.

The dissemination of erratic blocks is also attributed to the action of glaciers. We observe these in the plains of Switzerland and of Piedmont; it is ice which has detached them from the sides of the Alps, and ice which has transported them to the place where they now rest. Some naturalists have introduced water as an agent in this matter, which according to them must have covered certain parts of Europe to explain the transportation of these bowlders. This hypothesis has, however, been abandoned even by its illustrious author;§ for had the

* Cotta, *Briefe über Al. v. Humboldt's Kosmos*, vol. 1, p. 216.

†Alph. Favre, *Recherches géologiques*, t. i, p. 183.

‡ E. Desor, *La Limite Sup. des Polis Glaciaires*, etc., 1855, p. 7.

§ Lyell, *Elements oj Geology*, 6th edit., t. i, p. 229.

transportation been accomplished by water, shells would be found in the *drift*, which is not the case.

The members of the geological commission of Canada* have found many transported blocks both in the mountains and in the valleys of this province. The blocks of each locality consist of a mixture of different rocks, although one of local or distant origin strongly predominates over the others. In almost every case the blocks seem to have been transported toward the south." There are some signal exceptions, however. Thus, in the county of Runouski, in the valley of the river Neigette, there are several calcareous bowlders transported from a distance of several miles in an opposite direction from the ordinary, that is, to the northeast. Dr. Dawson has observed similar instances in Nova Scotia. This phenomenon is not confined to the northern hemisphere.† Darwin discovered the existence of similar blocks in South America, and almost within the same limits, that is to say, about 50° 10′ of south latitude. About the seventy-second degree of west longitude these boulders are very numerous. They consist of feldspathic rocks, of the schists, chlorites, quartzes, and the basaltic lavas. This phenomenon, then, is very general, and consequently every theory which attempts to explain it by any local cause must be discarded. In proportion as we approach the tropical regions the phenomenon gradually disappears, and no trace of it is found beyond the forty-fifth degree of latitude north or south. It is, therefore, almost impossible to suppose that the bowlders of one hemisphere were carried into the other, and consequently it must be admitted that this phenomenon occurred periodically upon each of the two hemispheres.

If we admit that a very general cause must have presided over the dissemination of these transported blocks, still we cannot deny that sometimes a local cause may produce the same phenomenon. North America furnishes an example of this. In Canada the mean temperature of winter is 9° 9′, and in Labrador it is still less. The winters there are very rigorous, producing the congelation of the mouths of the river Saint Lawrence, as well as of the rivers which empty into Hudson's Bay, among others of the Saskatchewan, and the Churchill. As this barrier of ice occurs when the winter rains of the northern part of North America produce great inundations, it is violently broken up, and the ice of the submerged plains is carried away, with everything which has collected upon it. This cause of the dissemination of bowlders cannot be generalized, for the simple reason that the periodical rains in Europe do not always occur in winter.

To explain the phenomena of erratic boulders most scientists have recourse to ice; and differ only in regard to the cause which could produce an extension of the glaciers. Thus Charpentier supposed that the

Report, Montreal, 1864, p, 947.

†*On the Distribution of Erratic Boulders, etc.* Trans. Geolog. Soc., London, 3d ser. vol. vi, p. 415.

change of climate of Switzerland ought to be attributed to the elevation of the Alps. In 1841 he abandoned this idea to support that of the rending of the Alps, and the ejection from the fissures formed of large quantities of vapor, which in precipitating cooled the country.

M. Kæmtz was inclined to suppose a still greater elevation of the Alps, as much as 20,000 feet. According to M. Lecocq, it is the unequal distribution of heat at the surface of the globe, which on the one hand favors the evaporation of the waters, and on the other the precipitation of these vapors. M. de la Hive attributes to the evaporation of the waters of the freshly-emerged continents, the formation of the more extended glaciers of some mountain chains. Mr. Frankland* proposed a theory which rests upon the fact of the unequal cooling of the ocean and of continents. The sea, retaining the heat better, at a certain period disengaged vapors, which were precipitated in the form of snow, the fusion of which during the summer absorbed a large part of the heat, so that the temperature of the continent was sensibly diminished. M. Escher de la Linth thinks that the *feune* (Föhn) warm wind from the sea could not blow at a period when as we suppose the Sahara was a sea. Switzerland must have been then much colder.† Still other hypotheses have been proposed, but not so much of the character of a general and periodical cause.

The variations of temperature which occurred during geological periods is most frequently explained by the presence or absence of the Gulf Stream. We have in fact seen that the oceanic currents as well as the aerial currents are variable in their direction and in their intensity. It only remains to explain why the marine currents as well as the winds are more intense in the austral than in the boreal hemisphere; why all the most important currents, and the Gulf Stream itself, have their starting-point in the three *drifts* of the Antarctic glacier, while the Arctic currents are comparatively of little importance. We answer that it is the unequal distribution of water and the unequal size of the two glaciers which produce this variable intensity of the currents in general; but to what can we attribute the disproportionate extension of the austral glacier and the predominance of water in the corresponding hemisphere? This explanation of the unequal temperature of the two hemispheres and of the oscillation of climates in geological epochs is not sufficient, for one might as well take the cause for the effect of the change of temperature.

Great progress, however, was made in the admission that the climatic condition of the globe has not always been the same, and that the cold which now prevails upon the austral hemisphere, formerly covered with a stratum of ice a part of Europe and of Asia. It was a chamois-hunter, of the valley of Bagne, named Perraudin, who suggested the idea to Charpentier that the erratic blocks which incumbered the valleys might

***Phil. Magaz.*, August, 1864.

†Favre, *Rech. Géolog.*, t. i, pp. 185–190.

have been transported thither by the glaciers at the time of their greatest extension.* Charpentier developed this theory, and to him is due the honor of having introduced into science a fact now generally admitted.

This new theory was supported by the authority of Professor Agassiz, but immediately there was a division of opinion among glacialists; some believed, with Agassiz, that a Siberian cold reigned throughout all Europe, and that all the northern part was covered with a cap of ice; others, with Charpentier, admitted only glaciers of gigantic dimensions. Sir Charles Lyell was one of the most active defenders of this theory, which he developed in his numerous works.

Geologists are not in accord as to the number and duration of the glacial periods. Some maintain there was a single period of cold; others two or several, limited to a certain epoch, beyond which the existence of ice was hardly probable. M. D'Archiac† thought that the polar ice did not exist beyond the Tertiary period. However, the fissures or flaws in the Permian, Liassic, and Cretacean deposits, as well as the arrest of animal and vegetable life, prove, it seems to us, that the climate underwent great changes, not only during the Tertiary and Quaternary periods, but also during the above-mentioned formations. Climates have varied very little since the Coal period, for the coal-beds are found in the same zone to which turf-marshes are now almost exclusively confined. In proportion as we advance toward the south of Europe, says M. Lesquereux, we cease to find coal beyond the limits which contain peat-bogs, and towards the north the thickness of the coal-beds is in relative proportion to the thickness of the peat-deposits in the neighborhood. The same fact may be stated for the austral hemisphere, and neither coal nor peat is found between the tropics.‡

It must, however, be admitted that notwithstanding this localization of climates the temperature was less extreme in the two opposed seasons, and there was greater moisture, on account of the preponderance of water in the austral hemisphere. The same thing is repeated in the Tertiary period; the European flora, analogous to that of New Orleans, indicates a damp and marshy climate. The temperature, however, could not have been much higher than it is now, or the existence of peat-bogs would have been impossible.§ We know, moreover, the slowness of the process of the cooling of the crust of the globe. If we calculate the temperature of the latter for a supposed age of the Coal period, or even an earlier, we find that the quantity of heat radiated into celestial space, although necessarily greater than at present, could not sensibly have influenced the modification of climate. As the radiation of the central heat of the earth acted almost under the same condition as to-

* Favre, *Rech. Géol.*, t. i, pp. 57, 178.

† *Cours de Paléont. Strat.*, t. ii, p. 29.

‡ D'Archiac, *op. cit.*, p. 403.

§ Dr. Oswald Heer, *Flora Tertiaria Helvetiæ*, t. i, p. 12; t. iii, p. 324.

day, and could not, consequently, raise the temperature of the atmosphere, we may say that the modification of climate depended in part upon the distribution of seas and continents, but principally upon solar heat, and the geographical position of a region. Starting with these facts we will endeavor to find the cause which may have changed the climatic conditions and produced glacial periods.

The geographical position of a place has great influence upon the nature of its climate; and this influence would be much greater if the distribution of continents and of seas was uniform. Since this is not the case the mean temperature of different parts of the globe, notwithstanding their geographical position, may be perfectly identical, although in two distinct latitudes; and very different although in the same position in regard to latitude. Proximity to the sea renders a climate more uniform. Thus in Ireland, plants of Southern Europe grow in the open air, which would freeze in the same latitude in Germany. On the other hand, the summers of Ireland are rainy and even cold enough sometimes for snow, when in Germany the vines ripen upon the Rhine, and the summers are warmer than at Rome.

The continental climates are more extreme in the two opposite seasons, which is shown by the enormous difference between the two limits of temperature at Moscow, equal to about 70° Centigrade. The winters of Pekin are as severe as those of Upsal, while the summers are as burning as those of Cairo. Mr. Lyell thinks the conversion of the sea into dry land, and the land into sea, the increase and diminution of the height of the mountain-chains and of continents, the predominance of land or of water in high and low latitudes, and, finally, a new direction given to the currents of the ocean, such as the Gulf Stream, were changes of a nature to modify the climates of the globe.* We cannot deny that a change in the distribution of continents and of seas would be followed by an equal change in climates, and Mr. Frankland has shown† that if the continents were distributed about the poles, while the sea formed a belt around the equator, the water, the most proper vehicle of heat, would warm the polar regions at the expense of the equatorial zone; but the periodic return of the same phenomena of refrigeration appears to proceed from laws more simple and constant.

As the sun is the principal source of heat for all the surface of the globe, certain causes, which modify its calorific intensity, equally affect the climatic conditions of the earth. This modification may take place in two ways. First, the intensity of the solar heat may itself vary. In fact it has been proved that the solar spots are subject to a periodic return, and by enfeebling the calorific power of the sun, sensibly affect the temperature of the terrestrial surface. There is nothing, then, untenable in the supposition that the sun in its quality of a variable star was formerly subject to greater physical perturbations, and that, consequently, the

* Lyell, *Elements of Geology*, vol. i, p. 287.

† *Phil. Magaz.*, August, 1864.

production of a large number of spots diminished the radiant heat and occasioned great cold. But this supposition, nevertheless, remains in the doubtful region of the merely probable, and can by no means be considered a settled fact. Secondly, it is quite otherwise as to the relative position of the earth to the sun; for a change in this position can be submitted to exact calculation, and the influence readily determined it would exercise upon the fluid envelope of the globe, which, by its mobility, is the true regulator of climates.

The distance of the earth from the sun changes by virtue of the eccentricity of the terrestrial orbit, which has not been the same throughout all periods, for it is diminishing now and will continue to diminish for twenty-three thousand eight hundred and eighty years, commencing from 1900 to increase again. Its smallest limit, according to Leverrier, is 0.003314, and its greatest, 0.07775, a difference sufficient to impress, by the alteration in the intensity of the sun's heat, a distinct character upon the organisms of the corresponding epochs.* When the eccentricity is very great, the sun is sensibly nearer to the earth at the perihelion. The temperature will then increase in inverse proportion to the square of the distance, while, for the same reason, the heat will diminish at the aphelion. This change will also affect the quantity of heat which the earth annually receives from the sun. If, in fact, the great axis remains invariable during all variation of eccentricity, the temperature must diminish, by virtue of the law that the total amount of heat received from the sun during a revolution of the earth is inversely proportional to the small axis, for the small axis diminishes when the eccentricity increases, and *vice versa.* But as the difference of the small axis of the terrestrial orbit between its two extremes is only 0.003 (as 997 is to 1,000), this small quantity cannot sensibly affect climates, and it would not be of any great consequence if it were omitted altogether.

The value we place upon eccentricity is otherwise very important; for when it is at the maximum, the distance which separates, at the aphelion, the earth from the sun is 32,706,262 leagues (20 for a degree), and when at the perihelion its distance is only 28,176,478 leagues. The difference, 4,529,784 leagues (15,000,000 miles), shows that the earth is by that amount nearer to the sun at the perihelion than at the aphelion. The direct heat of the sun being inversely proportional to the square of the distance, it follows that the quantity of heat received by the earth in the two positions will be as 19 to 26.

If we now suppose that, according to the precession of the equinoxes, the winter of the boreal hemisphere coincides with the aphelion of the terrestrial orbit to the period when the eccentricity is greatest, the earth would then be 2,886,599 leagues (10,000,000 miles) farther off than it is now. In consequence, the direct heat of the sun would be diminished a fifth of its present intensity, and the difference between the temperature of the two extreme seasons would increase double that

* H. G. Bronn, *Handbuch einer Geschichte der Natur*, t. i, p. 427, c.

amount. If, on the contrary, under the same circumstances, the winter coincided with the perihelion, the earth would then be 4,529,784 leagues (over 15,000,000 miles) nearer the sun during the winter than in summer, and consequently the difference between the two seasons would be almost annihilated in our latitudes. But as the winter of one hemisphere corresponds with the summer of another, it results that while one hemisphere is subjected to the alternate influence of extremes of heat and cold, the other, on the contrary, enjoys a perpetual spring-time, or, we may better say, a uniform climate.

It is true that, according to J. Herschel,* the quantity of heat the earth receives from the sun is proportional to the angle the earth describes in passing over any part whatever of its orbit, or, which amounts to the same thing, the sum of heat received between the vernal and autumnal equinoxes is constant for two parts of the year, whatever may be the eccentricity of the orbit. It results, then, that the greater heat of the summers of one hemisphere are exactly compensated for by their short duration, while the summers of the opposite hemisphere, notwithstanding the great distance from the sun, receive, on account of their length, the same amount of heat as the warm summers of short duration. The same comparison may be applied to the winters of the two hemispheres. These considerations induced Herschel to deny all influence of the eccentricity and of the precession of the equinoxes upon the distribution of solar heat upon the surface of the globe. And this is the cause of the refusal of many geologists to recognize the connection which exists between these cosmical phenomena and the variations of temperature which have taken place in geological periods.

But Humboldt observed that the temperature of the globe depended as much upon the quantity of heat radiated into celestial space as upon the heat proceeding directly from the sun, and the principle of compensation might be applied to the latter but not to the former. It is in fact well known that the temperature of a place rises whenever the days are longer than the nights, and falls, on the contrary, when the nights are the longer.† Now the austral hemisphere has not only a more rigorous climate, on account of the greater distance of the earth from the sun, but the winter is also longer, and the number of its nights greater. The length of the winter, the small quantity of heat received from the sun, and the heat lost by radiation and not compensated for, contribute to cool the hemisphere to such a point that the humidity produced by the evaporation of the waters in the tropical regions is principally precipitated upon this hemisphere, which, by its coldness, acts as a condenser. The result is an accumulation of snow and ice in the temperate and cold regions, which prevents the action of the solar heat by absorbing a large portion for their fusion.

The direct action of the sun is also prevented by the precipitation of

* *Transactions Geolog. Soc. Lond.*, 2d ser., vol. iii, p. 298.

†J. Adhémar, *Révolution de la Mer*, 2d edit., 1860, p. 16.

the vapors coming in contact with the ice and snow; fogs and clouds are besides formed which absorb heat from the sun, it is true, but they easily lose it again by radiation because of their elevation and their position in a less dense atmosphere. One would suppose that the summer rains were in themselves sufficient to melt the snow accumulated during the winter; but such is not the case, for eight parts of water, at 10° centigrade, are necessary to melt one part of snow, even when this has commenced to dissolve. Professor Forbes has found that only the fifteenth part of the snow of Norway is melted by the rains of summer, which are there very abundant.

If, then, at the time of the maximum of eccentricity the mean temperature of winter fell to a fifth below the present mean, and if the length of the day in winter was increased in proportion, it is probable that the climate of Central Europe would unite all the conditions for producing the extraordinary development of the glaciers, indicated by the traces of their action. The heat of the summer increased a fifth would not prevent the insensible deterioration of the climate, and we have a beautiful example in the island of Georgia of the south, of permanent ice in a latitude where in Ireland palms grow in the open air.* Navigators have seen in Terre del Fuego and in the straits of Magellan, snow fall in the middle of summer, and it has been proved that the temperature of this season rarely rises above 6° and almost never above 10°.

Such would be the condition of our climates, if, after the reaction from great eccentricity, the winters coincided with the aphelion. This state of things would not even be modified by the Gulf Stream; this would prevent the congelation of the European seas, but not the detachment of icebergs from the glaciers which would have attained the level of the sea, and the masses of ice floating around the islands and continents would cool them considerably by their fusion. There are numerous examples of a remarkable coincidence between the presence of floating ice in the vicinity of an island or a continent, and the return of cold weather after the mildness of spring. Not long ago the inhabitants of Iceland were reduced to the utmost misery by the accumulation of floating ice, which, by the cold it occasioned, destroyed the harvests. Some exceptionally warm years following 1814 were the cause of the breaking up of the ice of Greenland.† The floating ice descended upon the occidental coasts of Europe, which produced great cold, and in consequence the glaciers of the Alps increased in a most unusual manner.

But it is a question whether the Gulf-Stream and other currents will always exist in their present intensity. In seeking the causes of oceanic currents, we find in the unequal temperature of the poles and of the

* Captain Cook landed on his second voyage upon this melancholy island, and he says of it: "We thought it very extraordinary that an island between the latitude of 54° and 55° should, in the very height of summer, be almost entirely covered with snow, in some places many fathoms deep." (*Captain Cook's Second Voyage*, vol. ii, p.232.)

†Arago, *Œuvres, Rapports*, &c., p. 118.

equator the principal motor of the liquid envelope of the globe. Now, if the difference between these two temperatures was moderated, the intensity and direction of the currents would be modified in proportion. In fact, the austral hemisphere is the colder, and from the Antarctic pole proceed the principal oceanic currents. The grand current of cold water which passes into the Pacific ocean is divided into two. One arm passes by the Asiatic archipelago and joins a second current of cold water, which expands itself in the Indian Ocean. These two currents united, then pass to the west, around the Cape of Good Hope, and join a third austral current which passes along the western coast of Africa, and finally turns toward America, forming what is called the equatorial current of the Atlantic. Near Cape Saint Roque this current is divided into two; the principal branch enters the Gulf of Mexico and forms, when it emerges, the current of warm water known as the Gulf-Stream. The second branch passes along the coast of Brazil and is lost in the south.

A modification of the superficial heat does not act directly upon the intensity and direction of the oceanic currents, but rather upon the aerial currents which favor them. As there is a close relation between these two phenomena, an examination of their production will allow us perhaps to understand the influence of the cosmic causes upon the climates of the globe.

The cause of the aerial currents lies in the unequal density of the upper strata and the lower strata heated by contact with the seas, and still more by contact with the continents warmed by solar heat. The lower strata, rarified by the heat, rise in the atmosphere, while the ambient and cooler strata replace them, to be elevated in their turn when they are rarified by the heat. This tendency of atmospheric strata toward the line of the greatest heat continues to the poles, the cold of which tempers the tropical climates, while the ascending air produces currents inverse to the lower currents, and which go to heat the poles, transporting to them at the same time the humidity proceeding from the enormous evaporation of the torrid zone. But as the two hemispheres are unequally cold, the air is denser at a less distance in the hemisphere which is in a glacial state; consequently the currents must be more intense during the greater part of the year. This is in fact the case. Now the trade-winds of the southeast blow with greater force than those of the northeast, and the consequence is that the former extend even to the fifteenth degree of north latitude, while those of the northeast are very rarely felt south of the equator, and almost never beyond the sixth degree of south latitude. The equator of terrestrial heat depends entirely upon these aerial currents, for if we glance at an isothermal chart, we will see that the equator of heat passes for three-quarters of the terrestrial equator to the north of this line, and for one-quarter to the south. This shows in a sufficient manner that the solar heat, accumulated at the south of the equator, is carried by the winds and raises the temperature of the regions situated to the north of this line, and that, consequently, notwithstanding the astronomical compensation of J. Herschel, one of the hemispheres is heated at the expense of the other, by the intervention of the fluid envelope of the globe.

During the glacial period, the existence of which is no longer disputed, the climatic state was reversed; the aerial and oceanic currents (we will see in what condition) must have been stronger on the northern coast. The principal motor of the Gulf-Stream must not only have been less powerful, but the winds from the north being also more violent, the current had to contend against the effect of contrary winds. Instead, then, of dividing at Cape Saint Roque, the equatorial current could pass entire into the South Sea, and along the eastern coast of South America, to heat the Antarctic pole.

But, excepting the periodical influence of the refrigerating causes upon the climatic conditions of the earth and upon the distribution of currents, it is impossible to know to how remote a period the action of the Gulf-Stream extends; for a modification of the continents might have here opened a new passage for the marine waters or closed another which had for a long time existed, creating thus the great variety in climatic conditions, manifested to us by paleontology and geology Thus the Madagascan flora seems to indicate, by its Indian character, notwithstanding its proximity to Africa, that at a period quite recent, an oceanic current starting from India diverged toward Madagascar,* the reverse of what takes place to-day.

If the Gulf-Stream were reduced only one-half, this alone would produce a lowering of the mean temperature of all the northern part of Europe, and the glaciers would descend to the level of the sea. The temperature, which would be lowered enough for such an extension of the glaciers, need not fall more than 6° centigrade.

Not only cold but also humidity is necessary to the formation of large glaciers, and also to the lowering of the mean temperature of the year; for it is principally the snow accumulated during the winter which, by forming, so to say, large stores of cold, prevents the solar heat from raising the mean temperature of the summer. It is, as we have said, the upper currents, contrary to the trade-winds, which carry the humidity with which they are charged, to the polar regions, where it is precipitated in the form of snow.

The enormous evaporation from the tropical seas, estimated at more than five meters a year, produces oceanic currents analogous to the aerial currents. The ambient and subjacent strata replace without ceasing the evaporated water. This produces a general movement of the cold water toward the equator of heat, which varies with the seasons. The waters may be either favored or impeded in this movement by the trade-winds, and the latter are generally impelled toward the hemisphere in which the mean temperature is highest.

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* Richard, *Éléments de Botanique,* 1864, p. 347.

When, according to the calculation of Mr. Croll,* 850,000 years before 1800, the eccentricity was nearly at its lowest limits, the difference between the temperature of the summer at the perihelion, and of the winter at the aphelion, was certainly very great; but by virtue of the compensation of intensity by duration, the glacial periods could not have occurred. If, on the contrary, we consider what might be the influence of these extremes of temperature upon the movement of the fluid envelope, and upon the circulation of the liquid matter at the surface of the globe, we must come to the conclusion that, on account of the aerial and oceanic currents, and on account of the preponderant precipitation of humidity upon one hemisphere, the terrestrial globe is unequally heated on the two sides of the equator.

Before entering further into these considerations and showing that the eccentricity of the orbit and the precession of the line of the apsides are the principal causes of the geological cold periods, especially evident if we examine their influence upon meteorological phenomena, we will endeavor to show how causes the most insensible may often, by long accumulation of their influence, produce sensible effects, the origin of which very often escapes us. Theory tells us that all surfaces intercepting light and heat must reflect a certain quantity. The moon reflects light, but the best electro-thermometer does not indicate with any certainty the presence of reflected heat. This does not prevent scientists from believing that the earth's satellite reflects an amount of heat in proportion to the light reflected, and that this heat influences the mean temperature of the earth. Analysis of about 238,000 observations made during twenty-six years at Prague, by M. Ch. Zenger, shows, first, that when the obliquity of the lunar orbit attains its maximum, the mean of the annual temperature reaches its minimum (the barometric pressure in this case attains its greatest value); second, that the variations of temperature (as well as of pressure) are periodical; the duration of their period being half a lunar year (9.5 solar years); third, the variations of temperature are more sensible during the winter than during the summer months, for in the first case they are six times greater than in the second.†

From the time when the perfect equilibrium of the temperature of the two hemispheres was first broken until our day, we must attribute to slow and almost insensible causes the periodicity and alternation of conditions favorable and unfavorable for the organisms of the earth. In order to appreciate the action of the cosmic causes we are considering, let us suppose that the eccentricity of the terrestrial orbit is at its maximum, and that the winter of the northern hemisphere coincides with the aphelion. In this case the length of the winter will be 199.5 days, and that of the summer 165.5 days. The reverse will be the case

*_Phil. Magaz._, February, 1867, p. 120.

† C. v. Zenger, _On the periodic change of climate caused by the moon_, Phil. Magaz., June, 1868, p. 433–439.

for the opposite hemisphere; the length of the winter will there be 165.5 days, and that of the summer 199.5 days. But as the long summer will receive the same amount of heat as the short summer, on account of the distance from the sun, and as the same unequal distribution of the heat of the winters is balanced by an inverse unequal proximity to the central luminary, the sum of annual heat received from the sun is the same for the two hemispheres.

In like manner, the intensity of the aerial currents should be equal in the two hemispheres, if we except all accessory influence. Thus the northern hemisphere has a very warm summer, while the winter of the opposite hemisphere is of mean intensity. The difference which exists between these two correlative seasons of the two hemispheres should, by virtue of the compensation mentioned, be exactly equal to the difference which exists between the rigorous winter of the northern, and the temperate summer of the southern, hemispheres. The aerial currents depend, then, entirely upon the course of the sun, for generally the warmest place is that where the sun is at the zenith, and toward this place or this line the currents will be directed. It is evident that when the earth is at the equinoxes the two hemispheres are very nearly equally heated, consequently the aerial currents will be of the same intensity in the two parts of the globe. Let us suppose summer to commence in the southern hemisphere, the northeast trade-winds will blow from the beginning to the end of the season to the south of the equator, and displace, consequently, the line of greatest heat toward the austral pole. The upper currents, which sweep over an extent greater than the corresponding winds of the opposite hemisphere, will equally transport a greater quantity of humidity toward the north pole, where it will be precipitated, under the form of snow, on account of the great cold which reigns there. This phenomenon will occupy 199.5 days.

Now comes the summer of the boreal hemisphere. Its burning heat will contrast with the winter of the opposite hemisphere as the two preceding seasons, contrasted with each other; consequently from the spring equinox to the autumn equinox, the southeast trade-winds will blow to the north of the equator, as in the preceding case the northeast trade-winds blew to the south of the equator, and for 165.5 days an equivalent of humidity will be carried to the austral hemisphere. But these vapors are, in the first place, warmer than those of the austral summer; then the temperature of the austral winter, which, moreover, is the shorter, is elevated on account of the proximity of the sun. The vapors, therefore, carried to the south by the upper currents are resolved into rain instead of falling in the form of snow, as in the boreal hemisphere, and in consequence the solar heat of the next summer will be able without interruption to heat the surface of the earth, and raise the mean temperature of the climate. In the boreal hemisphere, on the contrary, a part of the heat is absorbed by fusion of the accumulated snow and ice, and the action of the sun weakened by the constant precipitations of the vapors and by the formation of fogs. To recapitulate, the equator of heat remains thirty-four days longer to the south of the terrestrial equator, and for as many days longer the humidity of the torrid zone is transported to the north, where the excessive cold of the winter condenses it and precipitates it in the form of snow. The vapors condensed south of the equator are only very seldom precipitated in the form of snow, and then only in high latitudes, the cold of winter being insufficient to produce congelation. The accumulation of snow in the boreal hemisphere and its almost complete absence in the temperate zone of the austral hemisphere contribute in various ways to lower the total heat of the boreal hemisphere. To the heat absorbed by the fusion of the ice, by the interposition of fogs and clouds, we should add the reflection of the calorific rays from the snow. In fact, the winters becoming more rigorous, the first result of this increase of cold will be the depression of the equatorial line of snow-falls toward the equator; the quantity of heat will not then be everywhere proportional to the sine of the angle of incidence, for a part of the heat is reflected by the bed of snow, an effect quite as important as the absorption by fusion of the ice or by the interception of fogs.

Let us remark also that the mean temperature of the summer can never rise in the presence of large quantities of ice and snow. Scoresby, in his voyage to Greenland, observed this curious fact, that the pitch with which his vessel was coated melted under the influence of the direct rays of the sun, while the ambient temperature was below zero; a thermometer exposed to direct radiation indicated 36° centigrade, and the ambient air was at —6°. This fact, in appearance so strange, accords perfectly with our ideas of the diathermanous properties of the air. Tyndal states that perfectly dry air is almost entirely incapable of absorbing direct heat. The air is then cooled by the contact with the ice, but it is not heated by the sun, hence the low temperature. If by evaporation the air is charged with humidity, still its temperature will not increase, for in proportion as it absorbs heat it immediately gives it up again to melt the ice, and the ambient temperature will remain invariable. If a stratum of ice were transported to the equator, the mean temperature would be lowered to a point not equal to that of Central Europe.

Since, in accordance with what we have just said, the glacial periods may depend upon a cause as general as the eccentricity of the earth's orbit, is there no way of determining the epoch of these extraordinary cold periods? Messrs. Leverrier, Stone, and Croll have formed some tables which indicate the value of the eccentricity at intervals more or less remote. We recognize easily by them when the action of ice must have been considerable at the surface of the globe, but we cannot tell at what time the last great glacial period occurred. Was it between 80,000 or 240,000 years ago, or between 700,000 and 1,000,000? If we adopt the first of these figures as nearest our period, then the second glacial epoch should coincide with the Miocene formation. The eccentricity then attained its maximum; it was 0.074664.

The deterioration of the climatic conditions of the globe is not constant in its persistence upon a hemisphere during the entire continuance of great eccentricity; it alternates by the combination of the eccentricity with the precession of the equinoxes. Let us consider the influence of the latter.

The precession of the equinoxes is produced by the attraction of the sun upon the protuberant part of the earth, which tends to restore the equator to the plane of the ecliptic, which would take place without the rotation of the earth. At every period of the year except at the equinoxes, every part of the equator above and below the plane of the ecliptic tends to fall into this plane, but at the same time a counteracting influence exists in the diurnal rotation; these two forces combined produce a resultant which cuts the ecliptic at a point much nearer than the place where the intersection would have occurred if the protuberance had not existed. The consequence is a displacement of the plane of the equator; the poles describe upon the starry vault a circle completed in about 25,900 years. This is the period of the precession of the equinoxes, if compared with the stars, but it is much less if compared with the great axis of the earth's orbit, which moves in the contrary direction. It is then only 21,000 years.

It was in the year 1248 of our era that the first day of the boreal winter coincided with the passage of the earth to the perihelion.* From this time until 1869 the major axis and the radius vector of the spring equinox approached 10° 40′ 39″. Observation showed that it was also from this period that the heat of the boreal hemisphere commenced gradually to diminish, while that of the austral hemisphere increased in proportion. It is certainly not merely a chance coincidence that in general the climate of Europe is deteriorating, that Greenland is covered with ice, that the colony of Iceland is disappearing, that ice encumbers the Spitzbergen Island, Behring's Strait, and Baffin's Bay. It should also be observed, that it was about this period that the glaciers of the Alps commenced to extend more and more, and that the culture of the vine has disappeared in many localities of France. On the other hand, to what must be attributed the diminution of the austral glacier, evident from comparison of the reports of Captain Cook with those of modern travelers, if not to an amelioration of the climatic condition of the austral hemisphere? Can we seriously attribute the retreat of the line of permanent snow in the Cordilleras to an elevation of this mountain chain?

All these facts must convince the mind that in fact the climate of the boreal hemisphere is deteriorating, while that of the opposite hemisphere is gradually improving, commencing at an epoch which coincides very

*J. Adhémar, *Les Révolutions de la Mer*, 2d edition, p. 25.

nearly with the time when the excess in the number of the days of summer and of autumn commenced to diminish.

If we admit that the precession of the equinoxes embraces a period of 21,000 years, then for 10,500 years the seasons will be reversed by relation to the perihelion. Our hemisphere will then be cooling during 9,779 years, the period of maximum cold, after which its temperature will gradually increase until the maximum of heat.

M. Adhémar, in his remarkable work published in 1842, has endeavored to connect this periodicity of the return of the extremes of cold and of heat with the periodical return of the waters upon the continents. He has attempted to prove that the idea of a universal deluge is justified by the facts of science. He brings forward some very just considerations to show that the periodical return of the waters is a very general phenomenon which cannot be attributed to any local cause, such as, for example, the irruption of the sea into a continental depression. The almost universal traditions of a deluge with the inhabitants of both continents cannot be attributed to a common source, for they are found not only with the semitic races, but with the Basques, the Celts, the Hindus, the Mongols, and many African tribes. In America, especially, these traditions are numerous and very varied, and often remarkable in their coincidence with that of the Hebrews. Some races speak of several deluges, but the greatest number mention only one. As to the extent of the deluge the traditions vary. Sometimes it is a tribe, sometimes a family, then all humanity which was destroyed, with the exception of a single family or one couple saved on the trunk of a tree, on an arch, or on the top of a mountain.*

The masses of bones found upon the hills and banks of Siberia equally prove that animals were overtaken and engulfed by the waters, and were covered with mud and sand. A proof has also been found in support of Mr. Adhémar's view in the erosion of entire deposits such as could have been produced only by currents of great rapidity. It has been ascertained also, through researches made in Canada, that these currents were directed principally from north to south. The periodic return of the waters has produced in the basins subjected to it alternate fresh and marine water.

If we examine attentively the unequal distribution of the continents on the surface of the globe, their form pointed toward the south, the depth of the austral seas which is at least three times that of the boreal seas, we must acknowledge that the position of the waters which cover the earth in relation to the solid portions is eccentric, and can be explained only by an unequal density of the different parts of the terrestrial mass, or rather by the existence of a solid mass upon the austral pole, which by its elevation produces a displacement of the center of gravity of the earth, and consequently changes the level of the sea.

The solid mass which, according to Mr. Adhémar, produces this dis-

* Fr. Troyon, *L'Homme fossile*, 1867, p. 140.

placement of the center of gravity of the earth, is a thick stratum of ice and snow with which the southern hemisphere is covered. When the winters of the boreal hemisphere coincide with the aphelion, the snow will collect upon that hemisphere; the austral glacier will melt, the waters will return to our continents, and will cover them to the depth of five or six hundred meters in the latitude of Paris. This elevation of the level of the sea will be double in the latitude of Greenland, and null upon the equator.

M. Adhémar made the eccentricity of the fluid mass too great, and, therefore, in his efforts to establish the time of the formation of the glacier, obtained exaggerated results. A cupola of ice from 20 to 40 leagues (from 69 to 138 miles) in thickness, occupying a space 400 miriameters in diameter, is difficult to imagine. We can, on the contrary, conceive great density of the ice, on account of the strong pressure. The mass of ice is, in fact, less, as well as the supposed eccentricity of the fluid envelope.

Still, the evident traces of water in localities at considerable heights imply a great displacement of the fluid mass, and consequently great accumulations of snow upon the pole. Thus the Alps must have been submerged after they had acquired their present form. The traces of water are seen in the lines of erosion upon the sides of the mountains, the marine shells found at high levels, and the alluvial terraces. The highest line of erosion is found, according to M. Sharpe,* at an elevation of from 9,000 to 9,100 feet. A deeply-marked line passes entirely around the mountains. The sea must have remained for a long time at this level. The elevation of the second line is about 7,500 feet. It is found in many parts of Switzerland, and was observed by M. Forbes. The third line is at a height of 4,800 feet. Analogous lines are found in Scotland, Sweden, and upon some of the African islands.

The circumstance, according to Mr. Adhémar, which most contributes to the cooling of a hemisphere is the greater duration of the nights as compared with the days. At present the year of the boreal pole is composed of 4,464 hours of day and 4,296 hours of night, while the reverse is the case at the austral pole. If we consider the year as a single day, the sum of duration of the nights surpassing the sum of duration of the days of the austral hemisphere, there will be loss of heat by radiation which is not compensated for by the solar heat. The reverse is the case in the boreal hemisphere; the sum of the days there is greater than that of the nights, therefore there will be conservation of heat. The difference of temperature between the two hemispheres will be equal to the heat lost by radiation in a hundred and sixty-eight hours, plus the heat received from the sun in the same length of time; that is to say, this difference is equal to three hundred and thirty-six times the quantity of heat the earth received from the sun or loses by radiation in an hour. When the eccentricity was at its extreme, this difference

* *Quart. Journ. Geolog. Soc.*, 1855, t. xii, 46, p. 102–123.

must have been four times greater, and this inequality of heat received and lost by radiation, combined with the other atmospheric causes of which we have spoken, would produce a considerable cooling of one hemisphere, which would be followed, as a consequence, by great extension of the polar glacier. The humidity necessary for the accumulation of the ice is furnished, as we have seen, by the upper aerial currents contrary to the trade-winds. The precipitation of this humidity necessitates renewed currents, and the entire glacier, when it attains certain dimensions, acts as a drain upon the neighboring atmosphere with force in proportion to its size. The long-continued precipitations of the humidity in the form of snow, unless a considerable portion melt, must at last increase the glacier to such a degree that it will influence the center of gravity of the earth, and produce a change in the position of the fluid matter of the globe.

The height of the accumulation necessary to produce this change might be calculated, were the volume of the waters known, their eccentricity, the extension of the two glaciers, the center of gravity of the earth, and that of the fluid mass. But as only a very uncertain estimate can be made of the mean depth of the seas, the result of such an attempt can only approximate reality. M. Adhémar compares the volume of the austral glacier to a stratum of ice, 20 leagues in height and extending uniformly like a cap over the sphere, having for its base the seventieth parallel. As the glacier at the outside edges is rarely less than a thousand yards in height, we may suppose that near the pole it is double that thickness. This enormous stratum of ice, which effaces the flattening of the earth at the poles, would be represented upon a globe, of the radius of a meter, by an elevation of $0^{m}.0214$.

Were we to reduce this mass one-half, one-quarter, or even more, its action would still be sufficient to produce a submersion of a large part of the continents of the boreal hemisphere, if on the return of the conditions of cold the north pole was covered with a cupola of ice analogous to that of the south pole. As these conditions of temperature change every 10,500 years, by virtue of the precession of the equinoxes, it must be at the end of this period of time that the waters are removed from one hemisphere to the other. This removal commences with the melting of the greater glacier and the increase of the small one. This action is at first very slow, but it progressively acquires great rapidity, and when, in the general breaking up of the ice, the lower stratum which rests upon the bottom of the ocean is carried away, the waters are dispersed with such velocity that the sedimentary surface is deeply furrowed and large blocks are transported to a great distance. It is easy to see that thus great currents must be produced twice from the north to the south, and twice from the south to the north, in the period of 21,000 years.

In all the hypotheses of M. Adhémar, the only conjectural point is the thickness of the austral glacier; the other facts are so evident that they can be admitted without difficulty. As to the unequal temperature of the two hemispheres, we must cease to attribute it to the unequal distribution of the waters; for the earth is undoubtedly in the best condition to retain its heat when there is a preponderance of the sea, as continents lose more heat by radiation.

The hypothetical character of a mass of ice so considerable, disappears, if we take into account the effects of the ancient cupola of ice which covered all Lapland, Northern Russia, Iceland, a part of North America, and Siberia. Some geologists, among others Professor Agassiz, affirm that a cupola of ice covered, during the glacial period, the largest part of our hemisphere, and that the erratic boulders of Central Europe are only the moraines of this immense glacier, which would justify in a certain point of view the celebrated remark of Humboldt, that the earth is formed by the union of two mountains by their base.

The objections made to the hypotheses of M. Adhémar cannot lessen its scientific value. Far from sharing the fate of many theories proposed to explain the great geological cold periods, it on the contrary gains more and more upon the minds of those who attentively examine the circumstances of the production of these phenomena. But while acknowledging its merits, the necessity of certain modifications should be recognized. Thus we may admit that the displacement of the center of gravity of the earth takes place every 10,500 years; but, as the present eccentricity of the earth's orbit is not great, the changes of temperature of the two hemispheres is not sufficient to produce great accumulations of ice upon one of the poles.

The configuration of the continents cannot then change much by the removal of the waters from one hemisphere to the other. It is only great eccentricities of orbit which can produce a general cooling of a hemisphere and accumulation of polar ice sufficient to produce any considerable displacement of the waters. Then the oceans invade the continents and cover them to heights corresponding to the lines of erosion observed by M. Sharpe.

The savans who have investigated the action of ice during the Silurian formations of the old red sandstone of the Cretaceous period, &c., have at the same time established the consecutive existence of conditions very favorable to the development of organic life. The characters of the plants and of the animals indicate a climate warm and uniform, which contrasts strangely with the severity of the climate of the glacial periods. Moreover, this uniform climate did not reign only in the temperate regions; even in the more elevated latitudes its influence prevailed. Of this the coal-beds of the island of Disco, alternating with deposits of clay, the submarine forests of the coast of Greenland, the fossil remains of vegetation found in Spitzbergen and upon several ice-covered islands of North America, are sufficient proof.

In the instances mentioned, we cannot suppose that the vegetable *débris* were transported by marine currents, nor that the combustible deposits were formed at the mouths of great rivers; for in several places in the island of Disco trunks of trees more than 30 centimeters (12 inches) in diameter have been found buried in the earth, and sometimes in a vertical position, which proves that these trees have vegetated in latitudes where now a stratum of permanent ice covers the barren rocks.

To show that climates were really at one time milder than they are now, we may give as an example Iceland, which possessed formerly a rich flora and magnificent forests. Now the dwarf birch, the weeping-willow, and a few more or less hardy shrubs are the only remains of the ligneous vegetation. Greenland also, as we know, was once completely free of ice and covered with the verdure from which it derives its name.

At certain periods the Polar Sea must have been not only entirely free of ice, but also quite warm, for we find in its deposits corals, *Eucrinites*, and other *Mollusca*, whose living representatives inhabit warm seas. The Carboniferous limestone, the, coal-beds, and especially the magnesian limestone of the high latitudes, are also witnesses of a warm and uniform climate, which extended to arctic regions, now the most desolate. As further proof, in Prince Island, at Wilkie Point, at 70° 20′ of north latitude and 119° 40′ of west longitude, Captain MacClintock found oolitic rocks, containing an ammonite (*Ammonites MacClintocki*) and other oolitic shells. At Katmay Bay, near Behring's Strait, we find the following oolitic fossils: *Ammonites Wossnessenskii*, *Ammonites biplex*, *Belemnites*, *Paxillosus*, *Unio liassinus*. Sir E. Belcher found in the island of Exmouth, 77° 16′ latitude north and 98° 20′ longitude west, upon an elevated bank 570 feet long. (173^{m}.28), above the level of the sea, bones which Mr. Owen recognized as belonging to the *Ichthyosaurus*.* To produce such effects the mean temperature should, according to M. Heer, be elevated 16° centigrade, for we find in the Miocene flora of Spitzbergen the beech, the plane-tree, the hazel-tree, and other species identical with the fossils of Greenland, and he thinks the poplar and pine once grew even upon the north pole. The *Sequoia Langsdorfii* is the most common tree of Ataukerluk Bay visited by M. Heer. The *Sequoia sempervirens* is the recent representative of these fossil trees. It does not, however, extend beyond the fifty-third degree of north latitude; for a mean summer temperature of from 15° to 16° centigrade is necessary for its existence. Fruits ripen only at a mean temperature of 17° to 18°. The cold of winter cannot descend below one degree.

To what must these great changes of climate of the polar region be attributed? The eccentricity explains a part of the phenomenon, for we know that, according to the precession of the apsides, sometimes it produces conditions favorable to the extension of organisms, sometimes it cools the hemisphere to such a degree that a large part of these organisms are destroyed. Notwithstanding this alternation of uniform climates and extreme climates produced by the eccentricity, this cause

*J. Croll, *Phil. Magaz.*, June, 1867, pp. 426, 427.

is insufficient to explain completely the exceptionally favorable conditions these polar regions have sometimes experienced. Other causes must have concurred to produce this result.

The change which the obliquity of the ecliptic undergoes has for a long time attracted the attention of geologists and physicists, but it has generally been concluded that this cosmic cause could not sensibly modify the mean temperature of the terrestrial zones. M. Croll* has examined this subject with unusual intelligence, and has come to the conclusion that in fact the change of obliquity of the ecliptic will not sensibly influence the temperate zone, but there will result a slight change in the tropical climate, and that the effect will be considerable upon the temperature of the polar regions.

These conclusions have been drawn from the following considerations: According to Laplace, the obliquity oscillates 1° 23′ 34″ from two sides of the obliquity in 1801. The quantity of heat received by the equator from the sun in our day is represented by 365.24 thermal days, by the poles 151.59 thermal days. When the obliquity attains its maximum, 24° 50′ 34″, the quantity of heat received by the equator will be 363.51 days, and by the poles 160.04 days. The equator will then experience a decrease in the quantity of heat represented by 1.73 thermal days, and the poles an addition of 8.45. When the obliquity of the ecliptic reaches the maximum, the quantity of heat received by the poles will be greater by an eighteenth than that it now receives; in other words, the poles will then receive as much heat as the 76th degree of parallel receives at the present time.

The greater obliquity would not change sensibly the mean temperature of the polar winters, although the cold zone (as well as the tropical zone) might be more extended. For, after the disappearance of the sun below the horizon, its rays are almost completely intercepted, so that a decrease of 1° 20′ 34″ would not modify sensibly the temperature of the poles. In the temperate regions the sun would to the same degree be less elevated during the winter, which would slightly increase the cold. The quantity of heat that the poles receive during the summer would be, on the contrary, enough increased to modify the mean temperature of the polar summer. In fact 8.45 thermal days in addition to an eighteenth of the total quantity of heat received from the sun, would raise the mean temperature 7° or 8° centigrade.

If to this direct augmentation of the solar heat we add the constant transfer of heat toward the poles and of cold toward the equator, we will obtain results which will explain in a satisfactory manner the elevation of temperature of certain geological periods. It is the fluid envelope of the globe which most contributes to the equalization of temperature; the aerial currents transport to the poles a certain quantity of heat, but much less than that carried by the oceanic currents. The Gulf Stream alone transfers to the polar regions a quantity of heat equivalent to that received by 320,000 square leagues at the surface of the equator.

* *Phil. Magaz.*, June, 1867, p. 130.

According to the estimate of M. Meech, the annual mean of heat received by the polar zone and upon a surface taken as unity, is the 454 thousandth part of the heat received upon the same surface at the equator. As the quantity of heat transported by the Gulf Stream is equivalent to the heat received by a surface of 659,344 square leagues of the Antarctic regions, and as the surface of these regions is 830,000 square leagues, the amount of heat transported toward the polar regions by the single oceanic current, is nearly as great as the heat received directly from the sun by all the glacial zone. The quantity of heat transported by the current is to the quantity of direct heat as 15 is to 18. The two quantities are completely equalized, if we take into account the absorption of heat in the atmosphere, which ought to be greater because of the obliquity of incidence.

The Gulf Stream does not transfer all its heat to the poles; it yields up a certain quantity in the temperate regions; but, on the other hand, this current is not the only one, and the combined action of all the oceanic currents united to that of the atmospheric currents, can considerably augment the action of the eccentricity and obliquity of the orbit and free the poles, at certain periods, of the ice which covers them. When the obliquity of the ecliptic was at the maximum and an eighteenth more of direct heat fell upon the poles, the effect was to modify the severity of the cold of the hemisphere under ice, and to facilitate on the other hand the melting of the snow upon the hemisphere which enjoyed a uniform climate. If a great obliquity coincided with the other cosmic causes which diversify the climates of the two hemispheres, their co-operation could produce these exceptional conditions of temperature, the influence of which upon the organic and inorganic world of different periods is well established.

CONCLUSION.

MAN.

Science can find no particular circumstance which has marked the appearance of man; nor can she more definitely fix the period when this king of creation, a title humanity is pleased to assume, entered into the possession of his domain. It has sometimes been supposed that certain great changes in the conditions of existence which were fatal to a great number of mammalia, at the same time prepared the conditions for the appearance of the human race.

For a long time it was a disputed question whether man preceded the later glacial phenomena; that is, if he might be found in the fossil state. Cuvier positively denied this; he would not admit that man was contemporary with the great mammals of the Quaternary period, and all his school, strong in the authority of their master, refused for a long time to accept opposing, although well-established, testimony.

Archæology prepared the way for the solution of this grave problem by laborious investigation of the ancient remains of the implements of human industry. We distinguish among these a *Stone age*, when only instruments of silex were used, indicating by their rude form the savage condition of the primitive tribes; then followed the *Bronze age*, which manifested a growing civilization by the working of metals and the preparations of alloys of copper and tin; and lastly the *Iron age*, which commenced with historic times and continues in our day.

At these different periods man was contemporary with a great number of now extinct animals, as is proved by the remains of his industrial implements, found mingled in the same strata with the bones of these animals. From the time when Esper discovered, in the cavern of Gelenreuth (Franconia), human bones with those of extinct mammalia, until our day, proofs of this kind have been so multiplied that the existence of fossil man is now one of the best established facts of science. Besides the discoveries of F. Frère, of Buckland, of Tournal, of Joly, M. Lartet discovered, in 1860, in a cave of Aurignac (Haute-Garonne), human remains mingled with the bones of animals which they had probably cooked and eaten there. M. Garrigou, of Tarascon, found some jaw-bones of the cat of the caves (*Felis cultridens*) polished and ornamented by the hand of man.

The most important discovery in favor of the antiquity of the human race was made in 1863 by M. Boucher, of Perthes. This was the famous human jaw-bone found at Moulin-Quignon, near Abbeville, in a place where previously numerous implements of quartz had been discovered. A lively discussion ensued among savans, who came from all sides to examine minutely into the authenticity of the discovery; and, a fact worthy of remark, the most incredulous yielded to the evidence presented. Only M. Élie de Beaumont positively denied the deposit in which it was found to be Quaternary. He thought it an alluvium quite modern. A more recent discovery, made in 1865 by MM. Lartet and De Vibraye, proves that man was contemporary with the *Elephas primigenius*. Upon a fragment of a tooth of the elephant with a mane, found in the caves of Dordogue, we readily distinguish the contour of this animal traced with a point evidently by contemporary man. The deposit was in this case diluvial.

If the discoveries of late years add some pages to the history of man, still the unresolved problem of the origin of the race remains with all its difficulties. "Man," says M. Troyon,* "appeared in America with the Quaternary period. He was established in several parts of Europe at the time of the retreat of the great glaciers; was witness to the powerful action of the diluvial waters. Hidden in the depths of caves or established upon the edge of the retiring seas, he saw disappear gradually from the center of Europe the cave-bear, the rhinoceros, the mammoth, the stag with gigantic horns, the reindeer, and the removal to other climates of various species of animals." But as to the origin of

* *L'Homme fossile*, 1867, p. 178.

the human race, as to the history of its infancy, it is lost in the night of the past, and we can only accept the assertion of M. de Quatre-fages,* proved by the contradictory results of the researches of the many distinguished savans engaged with these questions, that science has not even commenced to solve this important problem.

It has been attempted to estimate at least the antiquity of man of the age of the deposits which contain human implements. The Tinière, a stream which empties into the lake of Geneva, has at its mouth a cone formed by the torrent which, having been cut transversely by the railroad, was observed by M. Morlot† to consist of strata corresponding to the three ages of man. From the thickness of these strata, and from other local circumstances which must have influenced the formation of the cone, we arrive at an age of 10,000 years for the three strata. This estimation is not exaggerated, since these strata represent only a part of the deposit formed during each age; for a large portion must have been carried away by contemporary erosion.

The skull found in the alluvion of Mississippi implies, it is claimed, an age of 50,000 years. An analogous age of man is indicated by the peat-bogs of Denmark. The lower strata of these bogs contain the remains of the Scotch pine, the middle show a predominance of the oak, which in the upper is replaced by the beech. Man preceded the oak; he inhabited this country when the Scotch pine formed vast forests, as is proved by the traces of cutting instruments found in the trunks of the pine trees preserved in the bogs, as well as by the flint instrument found in the same stratum with this conifer.‡

We ought to say that all these estimates are relative, as well to the mode of sedimentation of the alluvion as to the formation of the peat-bogs, which may modify them considerably; still we may with safety conclude that man is much more ancient than we have been accustomed to believe.

Without entering into the question of the unity or diversity of the origin of the human race, let us consider what influence man has exercised upon the organic and inorganic worlds. When the first generations appeared, man, few in numbers, confined his activity to the search for food, for means of shelter, and defense against the attack of animals. In proportion as the number of men increased, and fruit, game, and other alimentary resources began to fail, man was impelled to greater exertion, in order to supply his needs and to protect himself from the variable influence of external condition. He learned to store his provisions, and to capture animals, which in time became tame, and so were laid the foundations of agriculture and domestication, the two powerful elements of progress and well-being of the human race. Since then man has made such progress that he now uses, to bring him into

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* *Origine des spécies animales et végétales*, Revue des Deux Mondes, t. lxxx, 1869, p. 672.

† *Bull. Soc. Géolog.*, 1860, second series, t. xviii, p. 829.

‡ Fr. Troyon, *L'Homme fossile*, p. 175.

the closest relations with nature, the same elements which formerly were an obstacle to his development.

In the course of a few hundred years he has developed an almost unlimited power of action, has accomplished more than could be produced by the other animals even during millions of centuries. Has he not raised the pyramids, built magnificent temples, tunneled entire mountains, raised enormous walls, erected monuments, cut through isthmuses, and disputed the possession of the land with the encroaching waves of the ocean? Has he not plowed the soil with iron, and are not the organic and inorganic world at his service?

Truly, to judge from his first efforts, man is destined to act a grand part upon the terrestrial globe, and although we cannot refute the assertion of M. d'Archiac that up to the present time there is nothing to prove that man is the end or last fiat of creation, nevertheless he unites in his nature such qualities that perfection outside of his race seems almost inadmissible. In proportion as the mind is developed, as the tendencies of man are refined and his activity becomes more in accord with his nature, in the practice of what is right and just, progress is made, and the great difference between the actual and the ideal man diminished.

Of what nature will be the modifications which the presence of man will produce in the configuration of the earth's crust? His antecedents allow us in some degree to imagine, but in all his efforts he will have to struggle against the effects of superior powers. Facts show us that upheavals and other great revolutions of volcanic nature become more and more rare in proportion as the earth advances in age; but what they lose in frequency they gain in intensity, so that we may doubt whether the Himalayan chain is the highest expression of their power.

The earth—will it ever become uninhabitable? Some savans do not hesitate to predict for it a destiny similar to that of the moon.*

It is true that increasing diminution of the fluid envelope may be considered as certain, but this diminution is extremely slow, and perceptible only after long intervals. We can nevertheless foresee that as the thickness of the atmosphere becomes less, cold will conquer all the globe. Oceans will be transformed into solid ice, and eternal snow will envelope the continents. Will organisms continue to exist under such circumstances? We do not dare to answer in the affirmative, although it is well known with what marvelous tractability organisms adapt themselves to circumstances produced by a slow change. But we can without hesitation affirm that if organized beings are destined to disappear from the surface of the globe by the influences of exterior causes, the most perfect, and humanity at the head, will go first, and the lower organisms remain the longest.

But this assuredly will not happen until nature has exhausted all her resources of combination; until matter, so to say, is tired of her con-

* See the interesting conclusion of M. Frankland, *Phil. Magaz.*, May, 1864, p. 431.

stant activity. A long repose will then follow the agitations of life, and the monotonous course of events will not even be interrupted by the periodical return of the orb of day. The brilliancy of the sun will also pale, while only the soft light of the stars will illuminate the frozen planet once our earth. As the finite is lost in the infinite, the earth, with its companions the planets, and the sun its guide, has only an ephemeral existence, and is of little moment in the eternal fecundity of the skies.

THE ASTEROIDS BETWEEN MARS AND JUPITER.

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PREFACE.

The discovery of the minor planets between Mars and Jupiter has opened to astronomers of the nineteenth century a new and highly interesting department of research. The wide diffusion of these planetary masses; the interlacing and approximate intersection of their orbits; the peculiar relations between some of their periods and that of Jupiter, the great disturbing force immediately exterior; and, finally, the bearing of these recently-discovered facts on the cosmogony of our system, all suggest important problems whose solution may require years of observation and research.

The views presented in the following paper have been briefly stated at different times* and sustained by such facts as were available at the time of publication. So rapid, however, has been the recent progress of discovery, and so remarkable the accordance of accumulated facts with the theory announced when but half the asteroids now known had been observed, that a revision of the whole snbject, including the latest discoveries, has been deemed desirable. The tabular elements adopted are taken from the *Berliner Astronomisches Jahrbuch* for 1877, except where more recent results have been obtained from the *Astronomische Nachrichten.*

THE ASTEROIDS.

1. It is proposed (1) to arrange the planets between Mars and Jupiter in the order of their discovery; (2) to tabulate their elements in the form most convenient for purposes of comparison; and then, (3) by a discussion of these elements in their mutual relations, as well as in their relations to Jupiter, the planet by which their motions are chiefly disturbed, to exhibit the evidence they afford in regard to the formation and development of the planetary system.

* Proc. of the A. A. A. S. for 1866; Meteoric Astronomy, chap. xiii; Monthly Notices of the R. A. S., vol. xxix; and Proc. of the A. A. A. S., for 1875.

TABLE I.—*The asteroids in the order of their discovery.*

No.	Name.	Date of discovery.	Name of discoverer.	Place of discovery.
1	Ceres	1801, Jan. 1	Piazzi	Palermo.
2	Pallas	1802, Mar. 28	Olbers 1	Bremen.
3	Juno	1804, Sept. 1	Harding	Lilienthal.
4	Vesta	1807, Mar. 29	Olbers 2	Bremen.
5	Astræa	1845, Dec. 8	Hencke 1	Driesen.
6	Hebe	1847, July 1	Hencke 2	Driesen.
7	Iris	1847, Aug. 13	Hind 1	London.
8	Flora	1847, Oct. 18	Hind 2	London.
9	Metis	1848, Apr. 25	Graham	Markree.
10	Hygeia	1849, Apr. 12	De Gasparis 1	Naples.
11	Parthenope	1850, May 11	De Gasparis 2	Naples.
12	Victoria	1850, Sept. 13	Hind 3	London.
13	Egeria	1850, Nov. 2	De Gasparis 3	Naples.
14	Irene	1851, May 19	Hind 4	London.
15	Eunomia	1851, July 29	De Gasparis 4	Naples.
16	Psyche	1852, Mar. 17	De Gasparis 5	Naples.
17	Thetis	1852, Apr. 17	Luther 1	Bilk.
18	Melpomene	1852, June 24	Hind 5	London.
19	Fortuna	1852, Aug. 29	Hind 6	London.
20	Massilia	1852, Sept. 19	De Gasparis 6	Naples.
21	Lutetia	1852, Nov. 15	Goldschmidt 1	Paris.
22	Calliope	1852, Nov. 16	Hind 7	London.
23	Thalia	1852, Dec. 15	Hind 8	London.
24	Themis	1853, Apr. 5	De Gasparis 7	Naples.
25	Phocea	1853, Apr. 6	Chacornac 1	Marseilles.
26	Proserpine	1853, May 5	Luther 2	Bilk.
27	Euterpe	1853, Nov. 8	Hind 9	London.
28	Bellona	1854, Mar. 1	Luther 3	Bilk.
29	Amphitrite	1854, Mar. 1	Marth	London.
30	Urania	1854, July 29	Hind 10	London.
31	Euphrosyne	1854, Sept. 1	Ferguson 1	Washington.
32	Pomona	1854, Oct. 26	Goldschmidt 2	Paris.
33	Polyhymnia	1854, Oct. 28	Chacornac 2	Paris.
34	Circe	1855, Apr. 6	Chacornac 3	Paris.
35	Leucothea	1855, Apr. 19	Luther 4	Bilk.
36	Atalanta	1855, Oct. 5	Goldschmidt 3	Paris.
37	Fides	1855, Oct. 5	Luther 5	Bilk.
38	Leda	1856, Jan. 12	Chacornac 4	Paris.
39	Lætitia	1856, Feb. 8	Chacornac 5	Paris.
40	Harmonia	1856, Mar. 31	Goldschmidt 4	Paris.
41	Daphne	1856, May 22	Goldschmidt 5	Paris.
42	Isis	1856, May 23	Pogson 1	Oxford.
43	Ariadne	1857, Apr. 15	Pogson 2	Oxford.
44	Nysa	1857, May 27	Goldschmidt 6	Paris.
45	Eugenia	1857, June 28	Goldschmidt 7	Paris.
46	Hestia	1857, Aug. 16	Pogson 3	Oxford.
47	Melete	1857, Sept. 9	Goldschmidt 8	Paris.
48	Aglaia	1857, Sept. 15	Luther 6	Bilk.
49	Doris	1857, Sept. 19	Goldschmidt 9	Paris.
50	Pales	1857, Sept. 19	Goldschmidt 10	Paris.
51	Virginia	1857, Oct. 4	Ferguson 2	Washington.
52	Nemausa	1858, Jan. 22	Laurent	Nismes.
53	Europa	1858, Feb. 6	Goldschmidt 11	Paris.
54	Calypso	1858, Apr. 4	Luther 7	Bilk.
55	Alexandra	1858, Sept. 10	Goldschmidt 12	Paris.
56	Pandora	1858, Sept. 10	Searle	Albany.
57	Mnemosyne	1859, Sept. 22	Luther 8	Bilk.
58	Concordia	1860, Mar. 24	Luther 9	Bilk.
59	Elpis	1860, Sept. 12	Chacornac 6	Paris.
60	Echo	1860, Sept. 15	Ferguson 3	Washington.
61	Danaë	1860, Sept. 19	Goldschmidt 13	Châtillon.
62	Erato	1860, Oct. —	Förster	Berlin.
63	Ausonia	1861, Feb. 10	De Gasparis 8	Naples.
64	Angelina	1861, Mar. 4	Tempel 1	Marseilles.
65	Cybele	1861, Mar. 8	Tempel 2	Marseilles.
66	Maia	1861, Apr. 9	H. P. Tuttle 1	Cambridge, U. S.
67	Asia	1861, Apr. 17	Pogson 4	Madras.
68	Hesperia	1861, Apr. 29	Schiaparelli	Milan.
69	Leto	1861, Apr. 29	Luther 10	Bilk.
70	Panopea	1861, May 5	Goldschmidt 14	Châtillon.
71	Feronia	1861, May 29	C. H. F. Peters 1	Clinton.
72	Niobe	1861, Aug. 13	Luther 11	Bilk.
73	Clytie	1862, Apr. 7	Tuttle 2	Cambridge.
74	Galatea	1862, Aug. 30	Tempel 3	Marseilles.
75	Eurydice	1862, Sept. 22	Peters 2	Clinton.
76	Freia	1862, Oct. 21	D'Arrest	Copenhagen.
77	Frigga	1862, Nov. 15	Peters 3	Clinton.
78	Diana	1863, Mar. 15	Luther 12	Bilk.
79	Eurynome	1863, Sept. 14	Watson 1	Ann Arbor.

TABLE I.—*The asteroids in the order of their discovery*—Continued.

No.	Name.	Date of discovery.	Name of discoverer.	Place of discovery.
80	Sappho	1864, May 2	Pogson 5	Madras.
81	Terpsichore	1864, Sept. 30	Tempel 4	Marseilles.
82	Alcmene	1864, Nov. 27	Luther 13	Bilk.
83	Beatrix	1865, Apr. 26	De Gasparis 9	Naples.
84	Clio	1865, Aug. 25	Luther 14	Bilk.
85	Io	1865, Sept. 19	Peters 4	Clinton.
86	Semele	1866, Jan. 4	Tietjen	Berlin.
87	Sylvia	1866, May 17	Pogson 6	Madras.
88	Thisbe	1866, June 15	Peters 5	Clinton.
89	Julia	1866, Aug. 6	Stephan	Marseilles.
90	Antiope	1866, Oct. 1	Luther 15	Bilk.
91	Ægina	1866, Nov. 4	Borelly 1	Marseilles.
92	Undina	1867, July 7	Peters 6	Clinton.
93	Minerva	1867, Aug. 24	Watson 2	Ann Arbor.
94	Aurora	1867, Sept. 6	Watson 3	Ann Arbor.
95	Arethusa	1867, Nov. 23	Luther 16	Bilk.
96	Ægle	1868, Feb. 17	Coggia	Marseilles.
97	Clotho	1868, Feb. 17	Tempel 5	Marseilles.
98	Ianthe	1868, Apr. 18	Peters 7	Clinton.
99	Dike	1868, May 28	Borelly 2	Marseilles.
100	Hecate	1868, July 11	Watson 4	Ann Arbor.
101	Helena	1868, Aug. 15	Watson 5	Ann Arbor.
102	Miriam	1868, Aug. 22	Peters 8	Clinton.
103	Hera	1868, Sept. 7	Watson 6	Ann Arbor.
104	Clymene	1868, Sept. 13	Watson 7	Ann Arbor.
105	Artemis	1868, Sept. 16	Watson 8	Ann Arbor.
106	Dione	1868, Oct. 10	Watson 9	Ann Arbor.
107	Camilla	1868, Nov. 17	Pogson 7	Madras.
108	Hecuba	1869, Apr. 2	Luther 17	Bilk.
109	Felicitas	1869, Oct. 9	Peters 9	Clinton.
110	Lydia	1870, Apr. 19	Borelly 3	Marseilles.
111	Ate	1870, Aug. 14	Peters 10	Clinton.
112	Iphigenia	1870, Sept. 19	Peters 11	Clinton.
113	Amalthea	1871, Mar. 12	Luther 18	Bilk.
114	Cassandra	1871, July 24	Peters 12	Clinton.
115	Thyra	1871, Aug. 6	Watson 10	Ann Arbor.
116	Sirona	1871, Sept. 8	Peters 13	Clinton.
117	Lomia	1871, Sept. 12	Borelly 4	Marseilles.
118	Peitho	1872, Mar. 15	Luther 19	Bilk.
119	Althea	1872, Apr. 3	Watson 11	Ann Arbor.
120	Lachesis	1872, Apr. 10	Borelly 5	Marseilles.
121	Hermione	1872, May 12	Watson 12	Ann Arbor.
122	Gerda	1872, Aug. 1	Peters 14	Clinton.
123	Brunhilda	1872, Aug. 1	Peters 15	Clinton.
124	Alcestis	1872, Aug. 23	Peters 16	Clinton.
125	Liberatrix	1872, Sept. 11	Prosper Henry 1	Paris.
126	Velleda	1872, Nov. 5	Paul Henry 1	Paris.
127	Johanna	1872, Nov. 5	Prosper Henry 2	Paris.
128	Nemesis	1872, Nov. 25	Watson 13	Ann Arbor.
129	Antigone	1873, Feb. 5	Peters 17	Clinton.
130	Electra	1873, Feb. 17	Peters 18	Clinton.
131	Vala	1873, May 24	Peters 19	Clinton.
132	Æthra	1873, June 13	Watson 14	Ann Arbor.
133	Cyrene	1873, Aug. 16	Watson 15	Ann Arbor.
134	Sophrosyne	1873, Sept. 27	Luther 20	Bilk.
135	Hertha	1874, Feb. 18	Peters 20	Clinton.
136	Austria	1874, Mar. 18	Palisa 1	Pola.
137	Melibœa	1874, Apr. 21	Palisa 2	Pola.
138	Tolosa	1874, May 19	Perrotin 1	Toulouse.
139	Juewa	1874, Oct. 10	Watson 16	Pekin.
140	Siwa	1874, Oct. 13	Palisa 3	Pola.
141	Lumen	1875, Jan. 13	Prosper Henry 3	Paris.
142	Polana	1875, Jan. 28	Palisa 4	Pola.
143	Adria	1875, Feb. 23	Palisa 5	Pola.
144	Vibilia	1875, June 4	Peters 21	Clinton.
145	Adeona	1875, June 4	Peters 22	Clinton.
146	Lucina	1875, June 8	Borelly 6	Marseilles.
147	Protogeneia	1875, July 11	Schulhof	Vienna.
148	Gallia	1875, Aug. 7	Prosper Henry 4	Paris.
149	Medusa	1875, Sept. 21	Perrotin 2	Toulouse.
150	Nuwa	1875, Oct. 19	Watson 17	Ann Arbor.
151	Abundantia	1875, Nov. 1	Palisa 6	Pola.
152	Atala	1875, Nov. 2	Paul Henry 2	Paris.
153	Hilda	1875, Nov. 2	Palisa 7	Pola.
154	Bertha	1875, Nov. 6	Prosper Henry 5	Paris.
155	Scylla	1875, Nov. 8	Palisa 8	Pola.
156	Xantippe	1875, Nov. 22	Palisa 9	Pola.
157	Dejanira	1875, Dec. 1	Borelly 7	Marseilles.
158	Coronis	1876, Jan. 4	Knorre	Berlin.
159	Æmilia	1876, Jan. 26	Paul Henry 3	Paris.

TABLE I.—*The asteroids in the order of their discovery*—Continued.

No.	Name.	Date of discovery.	Name of discoverer.	Place of discovery.
160	Una	1876, Feb. 21	Peters 23	Clinton.
161	Athor	1876, Apr. 17	Watson 18	Ann Arbor.
162	Laurentia	1876, Apr. 20	Prosper Henry 6	Paris.
163	Erigone	1876, Apr. 26	Perrotin 3	Toulouse.
164	Eva	1876, July 12	Paul Henry 4	Paris.
165	Loreley	1876, Aug. 9	Peters 24	Clinton.
166	Rhodope	1876, Aug. 15	Peters 25	Clinton.
167	Urda	1876, Aug. 28	Peters 26	Clinton.
168	Sibylla	1876, Sept. 28	Watson 19	Ann Arbor.
169	Zelia	1876, Sept. 28	Prosper Henry 7	Paris.
170	....	1877, Jan. 10	Perrotin 4	Toulouse.
171	....	1877, Jan. 13	Borelly 8	Marseilles.
172	....	1877, Feb. 5	Borelly 9	Marseilles.

REMARKS.

1. The numerals following the names of discoverers indicate the number of asteroids detected by each. Dr. Peters, of Clinton, N. Y., has discovered twenty-six; the greatest number first seen by any one observer.

2. The numbers discovered in the several months are as follows:

January	10	May	14	September	30
February	11	June	7	October	14
March	13	July	8	November	18
April	24	August	20	December	3

This obvious disparity is readily explained. The weather is favorable for night-watching in April and September; the winter months are too cold for continuous observations; and the small numbers of June and July may be referred to the shortness of the nights.

TABLE II.

NOTE.—d, represents the mean distance; P, the period; μ, the mean daily motion; e, the eccentricity; i, the inclination; π, the longitude of the perihelion; and Ω, the longitude of the ascending node.

ELEMENTS OF THE ASTEROIDS.

No.	Name.	d	P	μ	e	i	π	Ω
			d.	"		° ′	° ′	° ′
8	Flora	2.201	1193.01	1086.331	0.1567	5 53	32 54	110 18
43	Ariadne	2.203	1194.52	1084.950	0.1694	3 28	277 58	264 35
71	Feronia	2.266	1245.98	1040.147	0.1198	5 24	307 58	207 49
40	Harmonia	2.267	1246.95	1039.335	0.0465	4 16	0 54	93 35
18	Melpomene	2.296	1270.44	1020.120	0.2176	10 9	15 6	150 4
80	Sappho	2.296	1270.86	1019.781	0.2002	8 37	355 18	218 44
136	Austria	2.303	1276.93	1014.933	0.1132	9 41	307 12	186 9
12	Victoria	2.334	1302.73	994.835	0.2188	8 23	301 39	235 35
27	Euterpe	2.347	1313.48	986.694	0.1739	1 35	87 59	93 51
163	Erigone	2.351	1316.42	984.488	0.1490	4 41	93 17	159 0
169	Zelia	2.358	1322.55	979.698	0.1305	5 31	326 35	354 35
4	Vesta	2.362	1325.60	977.670	0.0884	7 8	250 57	103 29
84	Clio	2.363	1326.69	976.864	0.2360	9 22	339 20	327 28
52	Nemausa	2.365	1328.58	975.475	0.0672	9 57	174 43	175 52
30	Urania	2.367	1329.91	974.500	0.1266	2 6	31 46	308 12
105	Artemis	2.374	1336.41	969.766	0.1749	21 31	242 38	188 3
161	Athor	2.3760	1337.72	968.81	0.1328	9 10	312 56	18 33
113	Amalthea	2.377	1338.28	968.405	0.0879	5 2	198 58	123 12
115	Thyra	2.379	1340.67	966.644	0.1940	11 35	43 7	309 5
172	....	2.3795	1340.63	966.643	0.1005	9 41	326 17	331 48
7	Iris	2.386	1346.38	962.581	0.2305	5 28	41 23	259 48
9	Metis	2.387	1346.72	962.339	0.1233	5 36	71 4	68 32
142	Polana	2.387	1347.17	962.02	0.1054	2 18	227 23	292 36
60	Echo	2.393	1352.43	958.273	0.1838	3 35	98 36	192 5

TABLE II.—*Elements of the asteroids*—Continued.

No.	Name.	d	P	μ	e	i	π	Ω
			d	$''$		° ′	° ′	° ′
63	Ausonia	2.398	1356.29	955.545	0.1239	5 48	270 25	337 58
25	Phocea	2.400	1358.46	954.022	0.2554	21 35	302 48	214 13
20	Massilia	2.409	1365.82	948.883	0.1429	0 41	99 7	206 36
131	Vala	2.420	1375.21	942.399	0.0814	4 39	258 26	146 8
67	Asia	2.420	1375.38	942.282	0.1866	5 59	306 35	202 47
44	Nysa	2.422	1375.82	941.180	0.1507	3 42	111 57	131 11
6	Hebe	2.425	1379.32	939.595	0.2011	14 47	15 16	138 43
83	Beatrix	2.430	1383.64	936.662	0.0859	5 0	191 46	27 32
135	Hertha	2.432	1384.92	935.797	0.2036	2 18	318 45	343 59
112	Iphigenia	2.433	1386.57	934.679	0.0456	2 37	338 9	324 3
21	Lutetia	2.435	1388.29	933.554	0.1621	3 5	327 4	80 29
118	Peitho	2.436	1388.31	933.509	0.1638	7 49	77 4	47 13
126	Velleda	2.440	1392.08	930.979	0.1061	2 56	347 46	23 7
42	Isis	2.440	1392.22	930,906	0.2256	8 35	317 58	84 28
19	Fortuna	2.441	1393.43	930.076	0.1594	1 33	31 3	211 27
79	Eurynome	2.444	1395.24	928.874	0.1945	4 37	44 22	206 44
138	Tolosa	2.444	1395.34	928.805	0.1582	3 14	311 23	54 55
11	Parthenope	2.453	1403.17	923.622	0.0994	4 37	318 2	125 11
17	Thotis	2.462	1420.13	912.590	0.1293	5 36	261 37	125 24
46	Hestia	2.526	1466.79	883.564	0.1642	2 17	354 14	181 31
89	Julia	2.551	1488.22	870.841	0.1805	16 11	353 26	311 42
170		2.551	1488.22	870.841	0.0651	14 21	98 37	301 18
164	Eva	2.552	1489.52	870.079	0.3206	24 48	2 46	77 27
29	Amphitrite	2.554	1491.31	869.035	0.0742	6 7	56 23	356 41
134	Sophrosyne	2.567	1502.36	862.573	0.1172	11 36	66 52	346 30
144	Vibilia	2.575	1509.25	858.705	0.2286	4 51	8 31	76 45
13	Egeria	2.576	1510.59	857.945	0.0871	16 32	120 10	43 12
5	Astræa	2.579	1512.41	856.910	0.1863	5 19	134 57	141 28
119	Althæa	2.580	1514.02	856.000	0.0837	5 47	12 27	204 0
151	Abundantia	2.582	1514.42	855.775	0.0998	7 52	215 57	40 2
101	Helena	2.585	1518.00	853.752	0.1386	10 11	327 15	343 46
157	Dejanira	2.586	1518.64	853.392	0.2199	11 50	109 12	62 25
32	Pomona	2.587	1520.08	852.588	0.0830	4 46	193 22	220 43
91	Ægina	2.589	1522.06	851.477	0.1087	2 8	80 22	11 7
14	Irene	2.590	1522.13	851.436	0.1627	9 8	180 19	86 48
111	Ate	2.593	1524.83	849.928	0.1052	4 57	108 42	306 13
47	Melete	2.597	1528.68	847.790	0.2363	8 2	294 37	194 7
132	Æthra	2.601	1532.15	845.870	0.3820	25 0	152 11	259 44
70	Panopea	2.614	1543.56	839.614	0.1826	11 38	299 49	48 18
54	Calypso	2.621	1550.12	836.064	0.1301	5 6	92 47	144 4
78	Diana	2.623	1551.82	835.147	0.2053	8 39	121 9	333 55
124	Alceste	2.630	1557.60	832.049	0.0785	2 56	245 42	188 26
23	Thalia	2.631	1558.37	831.638	0.2299	10 14	123 58	67 45
15	Eunomia	2.644	1570.04	825.455	0.1872	11 44	27 52	293 52
37	Fides	2.644	1570.31	825.317	0.1758	3 7	66 26	8 21
66	Maia	2.649	1575.29	822.706	0.1655	3 5	46 21	8 17
51	Virginia	2.652	1577.44	821.586	0.2852	2 48	10 9	173 45
85	Io	2.654	1579.15	820.693	0.1913	11 53	322 35	203 56
26	Proserpine	2.656	1581.09	819.685	0.0873	3 36	236 25	45 55
102	Miriam	2.658	1586.32	816.985	0.3035	5 4	354 39	211 58
73	Clytie	2.665	1589.29	815.459	0.0419	2 24	57 55	7 51
97	Clotho	2.668	1591.70	814.222	0.2580	11 45	65 35	160 44
3	Juno	2.668	1591.99	814.077	0.2579	13 1	54 50	170 53
75	Eurydice	2.672	1595.42	812.388	0.3060	5 1	335 33	359 56
77	Frigga	2.672	1595.56	812.253	0.1345	2 28	60 23	2 1
114	Cassandra	2.676	1598.76	810.629	0.1401	4 55	153 6	164 24
64	Angelina	2.678	1605.16	808.021	0.1271	1 19	125 36	311 4
34	Circe	2.686	1608.30	805.819	0.1073	5 27	148 41	184 46
98	Ianthe	2.689	1610.39	804.774	0.1889	15 33	147 39	354 23
123	Brunhilda	2.693	1614.26	802.846	0.1136	6 27	72 5	308 40
145	Adeona	2.694	1614.97	802.489	0.2126	14 24	118 8	77 43
109	Felicitas	2.695	1615.96	802.001	0.3002	8 3	56 1	4 56
58	Concordia	2.700	1620.82	799.596	0.0426	5 2	189 10	161 20
103	Hera	2.701	1621.78	799.123	0.0803	5 24	321 3	136 18
140	Siwa	2.707	1626.72	796.693	0.1979	3 10	304 33	107 15
146	Lucina	2.708	1627.44	796.342	0.0672	12 42	237 38	84 18
55	Alexandra	2.709	1628.90	795.627	0.1897	11 47	294 16	313 49
141	Lumen	2.709	1629.01	795.575	0.2232	11 33	341 32	318 59
59	Elpis	2.712	1631.67	794.277	0.1189	8 37	17 33	170 26
166	Rhodope	2.720	1638.46	790.980	0.2386	11 41	30 52	129 15
45	Eugenia	2.720	1638.44	790.996	0.0826	6 35	228 54	148 14
110	Lydia	2.726	1643.69	788.468	0.0672	5 58	329 28	57 19
38	Leda	2.743	1659.53	780.942	0.1530	6 57	101 20	296 27
36	Atalanta	2.745	1661.32	780.102	0.3023	18 42	42 44	359 14
128	Nemesis	2.750	1665.74	778.030	0.1257	6 15	12 21	76 45
143	Adria	2.752	1668.00	776.989	0.0666	11 32	84 7	333 41
93	Minerva	2.754	1669.04	776.495	0.1405	8 37	274 44	5 4
160	Una	2.754	1669.52	776.271	0.0637	3 32	191 16	12 30
72	Niobe	2.756	1670.98	775.594	0.1732	23 19	221 17	316 30
56	Pandora	2.760	1675.15	773.663	0.1429	7 13	10 36	10 56
41	Daphne	2.760	1675.23	773.625	0.2704	16 0	219 59	179 13

TABLE II.—*Elements of the asteroids*—Continued.

No.	Name.	d	$P_\circ$	μ	e	i	π	Ω
			d	″		° ′	° ′	° ′
82	Alcmene	2.766	1679.98	771.437	0.2207	2 51	132 25	26 59
116	Sirona	2.766	1680.34	771.270	0.1439	11 35	152 53	64 26
1	Ceres	2.767	1681.41	770.780	0.0765	10 37	149 38	80 47
88	Thisbe	2.767	1681.46	770.760	0.1632	5 14	308 34	277 54
2	Pallas	2.772	1685.34	768.986	0.2385	34 42	121 53	172 47
39	Lœtitia	2.773	1686.44	768.483	0.1110	10 21	2 29	157 27
28	Bellona	2.777	1690.70	766.606	0.1531	9 22	122 23	144 44
68	Leto	2.780	1693.50	765.277	0.1385	10 51	345 14	45 1
74	Galatea	2.781	1693.68	765.196	0.2373	4 0	8 26	197 53
148	Gallia	2.783	1695.76	764.260	0.1844	25 40	39 37	145 18
99	Dike	2.797	1708.27	758.662	0.2384	13 58	240 36	41 44
139	Juewa	2.814	1737.00	751.642	0.0515	8 19	115 32	358 37
81	Terpsichore	2.853	1760.45	736.174	0.2110	7 56	48 42	2 45
33	Polyhymnia	2.861	1767.87	733.087	0.3400	1 56	342 25	9 12
129	Antigone	2.876	1781.33	727.547	0.2070	12 11	240 57	138 1
48	Aglaia	2.882	1786.95	725.259	0.1317	5 0	312 30	4 20
22	Calliope	2.909	1812.20	715.152	0.1012	13 44	59 58	66 35
16	Psyche	2.921	1823.42	710.753	0.1392	3 4	15 9	150 36
69	Hesperia	2.978	1877.00	690.464	0.1711	8 28	108 19	187 12
61	Danae	2.985	1884.17	687.837	0.1615	18 14	344 4	334 11
150	Nuwa	2.986	1884.66	687.714	0.1306	2 2	352 45	207 55
158	Coronis	2.990	1888.82	686.141	0.2921	1 23	355 10	282 49
117	Lomia	2.991	1889.12	686.033	0.0229	14 58	48 46	349 39
35	Leucothea	2.993	1890.64	685.483	0.2237	8 12	202 25	355 49
162	Laurentia	3.021	1917.98	675.710	0.1653	6 3	147 44	38 15
125	Liberatrix	3.035	1931.47	670.990	0.3468	6 5	251 17	117 16
156	Xantippe	3.036	1932.19	670.740	0.2637	7 29	155 58	246 11
96	Ægle	3.050	1945.31	666.220	0.1405	16 7	163 10	322 50
133	Cyrene	3.065	1959.74	661.310	0.1365	7 14	248 0	321 16
95	Arethusa	3.083	1977.36	655.468	0.1444	12 52	31 59	244 24
50	Pales	3.084	1978.23	655.131	0.2355	3 8	31 40	290 42
100	Hecate	3.091	1984.33	653.117	0.1639	6 23	308 3	128 12
53	Europa	3.101	1994.91	649.654	0.1068	7 26	107 32	129 49
86	Semele	3.112	2005.19	646.322	0.2101	4 48	29 44	88 5
49	Doris	3.113	2006.02	646.054	0.0717	6 29	70 27	185 13
120	Lachesis	3.120	2012.97	643.824	0.0471	7 1	212 52	342 52
159	Æmilia	3.125	2018.06	642.209	0.1155	6 5	135 5	135 5
147	Protogeneia	3.125	2018.75	642.174	0.0295	1 57	84 43	252 29
165	Loreley	3.129	2021.31	641.170	0.0726	11 10	282 24	304 1
62	Erato	3.129	2022.17	640.896	0.1734	2 12	38 36	125 49
130	Electra	3.130	2022.39	640.827	0.2041	22 56	20 18	146 8
152	Atala	3.132	2024.54	640.146	0.0822	12 10	80 0	41 29
24	Themis	3.136	2028.13	639.013	0.1242	0 49	144 8	35 49
90	Antiope	3.136	2028.85	638.786	0.1716	2 17	301 37	71 26
10	Hygeia	3.144	2036.46	636.398	0.1095	3 48	238 17	285 28
31	Euphrosyne	3.147	2038.95	635.620	0.2228	26 29	93 26	31 31
171		3.147	2039.31	635.509	0.1415	2 30	151 21	100 54
104	Clymene	3.151	2043.17	634.308	0.1773	2 52	58 22	44 21
57	Mnemosyne	3.155	2047.35	633.012	0.1093	15 10	55 4	200 15
106	Dione	3.159	2051.09	631.860	0.1805	4 38	26 58	63 24
94	Aurora	3.160	2051.80	631.641	0.0867	8 5	45 33	4 39
92	Undina	3.185	2076.27	624.190	0.1024	9 57	331 27	102 52
108	Hecuba	3.211	2101.90	616.585	0.1005	4 24	173 49	352 17
167	Urda	3.216	2109.12	614.475	0.3119	1 42	32 39	170 7
122	Gerda	3.220	2110.08	614.194	0.0114	1 36	208 38	178 55
154	Bertha	3.221	2111.46	613.792	0.1001	20 49	168 41	37 35
127	Johanna	3.321	2210.61	586.262	0.2040	8 33	101 24	31 23
168	Sibylla	3.378	2267.80	571.479	0.0671	4 35	5 43	209 36
76	Freia	3.409	2299.07	563.707	0.1739	2 3	92 47	212 14
65	Cybele	3.427	2317.19	559.298	0.1096	3 29	260 36	158 50
121	Hermione	3.461	2351.40	551.161	0.1217	7 35	0 56	77 0
87	Sylvia	3.482	2373.50	546.029	0.0790	10 55	335 17	76 2
107	Camilla	3.560	2453.62	528.200	0.1227	9 48	112 50	175 41
153	Hilda	3.950	2867.64	451.905	0.1631	7 51	285 2	228 20

DISCUSSION OF THE FACTS CONTAINED IN TABLE II.

3. *The theory of Olbers.*—The hypothesis that the asteroids are the fragments of an exploded planet was proposed by Dr. Olbers in 1802. While the known members of the group were but few in number, this bold conjecture seemed highly plausible; it has, however, been completely disproved by more recent discoveries. The breadth of the asteroid ring, as at present known, is greater than the entire interval between

the orbits of Mercury and Mars. Even the *least* distance of Hilda exceeds the *greatest* of Harmonia by one hundred and twenty millions of miles. It is, therefore, no more probable that the asteroids have all been produced by the disruption of a single planet, than that Mercury, Venus, the Earth, and Mars originated in a similar manner. The relative distances of Hilda and Flora, together with those of the four planets interior to the latter, are represented in the following figure.

1. Orbit of Hilda.
2. Orbit of Flora.
3. Orbit of Mars.
4. Orbit of Earth.
5. Orbit of Venus.
6. Orbit of Mercury.

4. *The small mass of the asteroids.*—In taking a general view of the solar system, we cannot fail to be struck by the remarkable fact that Jupiter, whose mass is much greater than that of all the other planets united, should be immediately succeeded by a region so nearly destitute of matter as the zone of asteroids. Leverrier, without attempting to determine the mass of the minor planets, infers from the motion of Mars's perihelion that it is certainly less than one-fourth of the earth's mass, or $\frac{1}{1200}$ of Jupiter's. Prof. Stephen Alexander estimates the mass at $\frac{1}{5431814}$ of the mass of the sun.* In other words, its ratio to the mass of Jupiter is that of 1 to 5180. We find, also, analogous facts in the secondary systems. Jupiter's third satellite, the largest of the number, is nearly four times greater than the second. Immediately within the orbit of Titan, the largest satellite of Saturn, occurs a wide hiatus, and the volume of the next interior satellite is to that of Titan in the ratio of 1 to 21. In the Uranian system, the widest interval between adjacent orbits is just within the orbit of the bright satellite Titania. No other secondary planet of our system contains so much matter in proportion to its primary as our own moon. Did this powerful mass prevent the formation or permanent existence of interior satellites?

5. The foregoing facts suggest the inquiry, What effect would be produced by a large planet on interior masses abandoned by a central spheroid? As the phenomena in all instances would be of the same nature, we will consider a single case—that of Jupiter and the asteroids.

The powerful mass of the exterior body would produce great perturbations of the rings or gaseous masses thrown off from the equator of the solar spheroid. The disturbed orbits, in some cases, would thus attain considerable eccentricity, so that the matter moving in them would, in perihelio, be brought in contact with the equatorial parts of the central nebula, and thus become reunited with it. The extreme rarity of the zone between Mars and Jupiter, regarded as a single ring, is thus accounted for in accordance with known dynamical laws.

* Smithsonian Contributions to Knowledge, No. 280, p. 33.

6. *Distribution of the asteroids.*—As long since as 1857, when the number of known asteroids was less than 50, it was inferred from physical considerations by the author of this paper that great irregularity must obtain in the distribution of these bodies, and that gaps or chasms would be found in those parts of the zone where the periods of asteroids would be commensurable with that of Jupiter. To verify this theory every addition to the group was watched with interest. In 1866, when the number had increased to 88, and the agreement between theory and observation had become quite marked, the attention of astronomers was called to the coincidence by a paper read at the Buffalo meeting of the American Association for the Advancement of Science. The comparison of fact and hypothesis has been continued to the present time; and it is now proposed to show that recent discoveries have confirmed the theory of an irregular distribution.

Assuming the equation

$$i\, n_a - i'\, n^v = 0,$$

where i, i', are any integers,

n_a=the mean daily motion of a planetary mass between the orbits of Mars and Jupiter,

n^v=the mean daily motion of Jupiter=299″.1286,

and assigning values at pleasure to i and i', we shall find those portions of the asteroid zone in which the periods would be commensurable with that of Jupiter. The following table contains *all* such instances when $i'-i<5$. The consideration of less simple cases of commensurability may be omitted.

	Values of n_a.	Corresponding distances from the sun.
(1.) When $i'-i=1$, $i=1$, and $i'=2$, or 2 periods of an asteroid=1 of Jupiter	598″.2572	3.27
(2.) $i'-i=2$, we have two cases:		
(α) $i=1$, $i'=3$	897″.3858	2.50
(β) $i=3$, $i'=5$	498″.5477	3.70
(3.) When $i'-i=3$, there are three cases:		
(γ) $i=2$, $i'=5$	747″.8215	2.82
(δ) $i=4$, $i'=7$	523″.4750	3.58
(ϵ) $i=5$, $i'=8$	478″.6058	3.80
(4.) When $i'-i=4$, we have also three cases:		
(ζ) $i=3$, $i'=7$	697″.9667	2.95
(η) $i=5$, $i'=9$	538″.4315	3.51
(θ) $i=7$, $i'=11$	470″.0592	3.85

These particular portions of the zone will be separately considered.

7. At the distance 3.27—which falls between the orbits of Bertha and Johanna—a planetary mass would make precisely two revolutions while Jupiter completes one. It is obvious, therefore, that all its conjunctions with that planet, for an indefinite period, must occur in the same parts of its path. Consequently its orbit would become more and more eccentric, until, if the nebulous ring had considerable density, the disturbed matter would be brought into contact, either in aphelion or perihelion, with masses having somewhat different velocities. The plan-

etary nucleus formed in this manner would be at some distance from the primitive orbit of the particle disturbed. A gap or chasm would thus be produced at the distance 3.27, or wherever the period of an asteroid would have to that of Jupiter a simple relation of commensurability. It may be objected that the mutual attractions of those primitive masses were too inconsiderable to result in the formation of planetary nuclei. But even granting the force of this objection, the fact still remains that the orbits of asteroids at the specified distances would increase in eccentricity till the masses in perihelio would reunite with the central nebula. In either case, therefore, chasms would be left in the primitive annulus. Let us now inquire whether the facts presented in Table II sustain the conclusions derived from physical considerations.

8. The mean distance of Hilda	=3.9505
That of Flora	=2.2014
Breadth of zone	=1.7491

As small bodies in the remoter parts of the ring are more difficult of detection, the zone will be considered under three divisions of equal breadth. The innermost section, A, extending from 2.2014 to 2.7844, contains 115 of the 169 asteroids whose elements are known; the mean interval between the consecutive orbits being 0.00511. Now the interval at the distance 2.50—between Thetis and Hestia—where an asteroid's period would be one-third of Jupiter's, is 0.0643, the widest in the section and about twelve times the mean interval. The middle section, B, extending from 2.7844 to 3.3675, contains 47 minor planets, the average interval between their consecutive orbits being 0.01268. The widest of these gaps, which is 0.1, or eight times the mean, is found at the distance 3.27, where an asteroid's period would be half that of Jupiter. Finally, the most remote section, C, extends from 3.3675 to 3.9505, including seven known asteroids. The mean interval in this section is 0.0972. The widest hiatus (between the orbits of Camilla and Hilda) contains the distances 3.58, 3.70, 3.80, and 3.85. The second in extent (between Sylvia and Camilla) contains the distance 3.51, where nine asteroid periods would be equal to five of Jupiter.

The nine distances * at which the periods of minor planets would have simple relations of commensurability to the period of Jupiter are thus found in the widest chasms of the zone. The result may be somewhat modified by future discoveries and by the more exact determination of orbits. The general features of the ring, however, depend on too wide an induction of facts to be regarded as merely accidental. The marked irregularity of distribution throughout the cluster is presented at one view in the following table:

Interior to the distance 2.25	2 asteroids.
From ....2.25 to 2.35	7 asteroids.
From ....2.35 to 2.45	32 asteroids.

* See table in 6.

From	2.45 to 2.55	3 asteroids.
From	2.55 to 2.65	26 asteroids.
From	2.65 to 2.75	28 asteroids.
From	2.75 to 2.85	19 asteroids.
From	2.85 to 2.95	6 asteroids.
From	2.95 to 3.05	10 asteroids.
From	3.05 to 3.15	19 asteroids.
From	3.15 to 3.25	9 asteroids.
From	3.25 to 3.35	1 asteroid.
From	3.35 to 3.45	3 asteroids.
From	3.45 to 3.55	2 asteroids.
Exterior to	3.55	2 asteroids.

In three portions of the ring the clustering tendency is here distinctly evident. These are from 2.35 to 2.45, from 2.55 to 2.80, and from 3.05 to 3.20. We have thus an obvious resemblance to the rings of Saturn; the partial breaks or chasms in the asteroid zone corresponding to the well-known intervals in the system of secondary rings. It may be remarked, moreover, that *all but one* of the nineteen asteroids between 2.75 and 2.85 are found in the inner half of the division; the outer half containing the distance at which five periods of a minor planet would be equal to two of Jupiter.

THE ECCENTRICITIES.

9. The mean eccentricity of the asteroids is 0.15683, while that of the eight major planets is 0.06025. It is worthy of note, however, that Mercury's eccentricity (0.20549) is even greater than that of the minor planets, and that the mean eccentricity of Venus, the Earth, Mars, Jupiter, Saturn, Uranus, and Neptune is but 0.03949. Of the asteroid orbits the least eccentric is that of Lomia, 0.02288; the most eccentric, that of Æthra, 0.38200. As with the orbits of the old planets, the eccentricities vary within moderate limits; some increasing, others diminishing. The average, however, will probably remain very nearly the same. The facts above noted indicate that the form of the orbits of Mercury and the asteroids was influenced by special causes. The mean eccentricities in the several parts of the asteroid zone are as follows:

Interior to	2.25	0.16307
From	2.25 to 2.35	0.15644
From	2.35 to 2.45	0.14930
From	2.45 to 2.55	0.13094
From	2.55 to 2.65	0.16286
From	2.65 to 2.75	0.17210
From	2.75 to 2.85	0.15474
From	2.85 to 2.95	0.18839
From	2.95 to 3.05	0.26182
From	3.05 to 3.15	0.13541

From... 3.15 to 3.25	0.13500
Exterior to......3.25	0.13014

Two maxima are observed; the first from 2.55 to 2.75; the second from 2.95 to 3.05. The orbits are least eccentric in the outer portion of the zone.

THE INCLINATIONS.

10. The mean of the inclinations of the asteroids now known is 8° 5′, one degree greater than that of the sun's equator. The least inclined orbit is that of Massilia, 0° 41′; the most inclined, that of Pallas, 34° 42′. The mean inclinations in different portions of the ring are given below:

	° ′
Interior to......2.25	4 40
From....2.25 to 2.35	6 52
From....2.35 to 2.45	6 34
From....2.45 to 2.55	4 10
From....2.55 to 2.65	9 22
From....2.65 to 2.75	8 8
From....2.75 to 2.85	11 50
From....2.85 to 2.95	7 19
From....2.95 to 3.05	8 54
From....3.05 to 3.15	7 45
From....3.15 to 3.25	7 0
Exterior to......3.25	6 51

The maxima are from 2.55 to 2.65, and from 2.75 to 2.85. Ten asteroids, one in seventeen, have inclinations greater than 20°. When we consider the great number of these bodies, together with the fact that in their primitive, gaseous form their dimensions must have been much greater than at present, it seems not improbable that collisions may have occurred between comets and asteroids. The masses of the former are doubtless in some cases comparable to those of the latter. In the event of such impact, therefore, the direction of the planet's motion might be very much modified. Possibly the rare instances of great inclination may thus be explained.

THE DISTRIBUTION OF PERIHELIA.

11. The longitudes of the perihelia of the asteroidal orbits are distributed as follows:

From 0° to 30°	19
From 30 to 60	25
From 60 to 90	13
From 90 to 120	17
From 120 to 150	13
From 150 to 180	9
From 180 to 210	8

From 210° to 240°	8
From 240 to 270	10
From 270 to 300	7
From 300 to 330	22
From 330 to 360	19

In the semicircumference from 300° to 120° are 115 perihelia, and in the remaining 180° only 55; the clustering tendency being obvious in the region adjacent to the perihelion of Jupiter.

THE SIMILARITY OF ADJACENT ORBITS.

12. An examination of Table II affords evidence of a similarity more than accidental between adjacent orbits of the asteroidal group; a resemblance pointing to a common origin. The orbits in some cases so nearly intersect that a future collision is by no means impossible. The striking similarity in the magnitude, form, and position of certain orbits will be seen by the following comparisons:

I.—FORTUNA AND EURYNOME.

	Fortuna.	Eurynome.
Distance	2.4415	2.4436
Period	$1393^d.43$	$1395^d.24$
Longitude of perihelion	31° 3′	44° 22′
Longitude of ascending node	211° 27′	206° 24′
Eccentricity	0.1594	0.1945
Inclination	1° 33′	4° 37′

II.—FIDES AND MAIA.

	Fides.	Maia.
Distance	2.6440	2.6495
Period	$1570^d.31$	$1575^d.29$
Longitude of perihelion	66° 26′	46° 21′
Longitude of ascending node	8° 21′	8° 17′
Eccentricity	0.1758	0.1655
Inclination	3° 7′	3° 5′

III.—CLOTHO AND JUNO.

	Clotho.	Juno.
Distance	2.6679	2.6682
Period	$1591^d.70$	$1591^d.99$
Longitude of perihelion	65° 35′	54° 50′
Longitude of ascending node	160° 44′	170° 53′
Eccentricity	0.2580	0.2579
Inclination	11° 45′	13° 1′

IV.—SIRONA AND CERES.

	Sirona.	Ceres.
Distance	2.7661	2.7673
Period	$1680^d.3$	$1681^d.4$
Longitude of perihelion	152° 53′	149° 38′
Longitude of ascending node	64° 26′	80° 47′
Eccentricity	0.1439	0.0765
Inclination	11° 35′	10° 37′

V.—URDA AND GERDA.

In the American Journal of Science for February, 1877, Dr. Peters, the discoverer of these asteroids, calls attention to several striking coincidences between the elements of their orbits. The mean distance, inclination, and ascending node of the former are very nearly identical with those of the latter. "The fact of two planets moving in the same plane, with the same time of revolution, having also the line of apsides in common,* but with a widely different eccentricity," as Dr. Peters justly remarks, "is worthy of note." The results of further observations will be looked for with interest.

CONCLUSION.

13. When the nebular hypothesis was proposed by Laplace, but four minor planets had been discovered. According to that hypothesis those new members of the system had been formed by the breaking up of a nebulous ring into fragments so small that no one had sufficient attractive force to unite the others about its center as a single spheroidal mass. After the number of asteroids had been largely increased the celebrated Plana regarded their phenomena as confirming, if not demonstrating, Laplace's theory. "The double fact," he remarks, "of the multitude of those bodies and of their circulation in the same direction around the sun, is now too imposing to admit an explanation of their origin and formation different from that developed by Laplace, in his Système du Monde."†

But the form and extent of the zone of the minor planets, as well as the known facts in regard to Saturn's rings, seem to require a modification of Laplace's theory. Throughout the greater part of the interval between Mars and Jupiter an almost continuous succession either of very narrow rings or of extremely small planetary masses appears to have been abandoned at the solar equator. The entire cluster, distributed throughout a ring whose outer radius exceeds the inner by 160

* The longitudes of their perihelia differ by nearly 180°.

† Note sur la Formation probable de la Multitude des Asteroïdes qui, entre Mars et Jupiter, circulent autour du Soleil. Par Jean Plana. Presentée le 2 Mars, 1856, à l'Académie Royale des Sciences de Turin.

millions of miles, could not have originated, as supposed by Laplace, in a single nebulous zone the different parts of which revolved with the same angular velocity.

The process of planetary separation, both exterior and interior to the zone of asteriods, was probably similar to that indicated above. The nebular hypothesis, in this view, assigns an obvious cause for the original formation of planetary nuclei in such positions that their periods would be nearly commensurable with that of the disturbing body. As these nuclei would receive accretions of matter from portions of space both exterior and interior to their respective orbits, their distances from the central body, during their planetary growth, would not be liable to great variation.

If anything can be inferred from the similarity of adjacent orbits pointed out on a previous page, it is that the minor planets so related were derived from the same nebulous ring or mass, and that the perturbations to which they have been liable have not yet wholly effaced this evidence of a common origin.

ETHNOLOGY.

THE LATIMER COLLECTION OF ANTIQUITIES FROM PORTO RICO IN THE NATIONAL MUSEUM, AT WASHINGTON, D. C.

By Otis T. Mason.

The remarkable beauty and finish of the stone implements of Porto Rico and others of the Antilles Islands are not wholly unknown to students of American Archæology. Now and then a small collection has found its way to London, Copenhagen, or New York; but they had never been collected in sufficient numbers for a comparative study until this important gift was bestowed on the Smithsonian Institution. For the convenience of description, the specimens may be separated into the following classes: *pottery*, *celts*, *smoothing-stones*, *mealing-stones*, *stools*, *discoidal and spheroidal stones*, *beads*, *cylinders*, *amulets*, *rude pillar-stones*, *mammiform stones*, *masks*, *and collars*. In some of these classes the objects are so similar to those found in other parts of America and throughout the world, that the briefest description will suffice. In others the number of specimens is so large, and the objects so rare, as to merit the most careful scrutiny and description. Whether from accident or design, there is not in all the collection a single flaked or chipped implement or weapon. Indeed, I have searched in vain in the National Museum for flaking or chipping from a Carib area. Although the historians of the voyages of Columbus mention arrows pointed with stone, they more frequently speak of bone, teeth, and shells as the materials used. Herrera, in speaking of their celts, says that they excavated their canoes with flint implements. (Herrera, Stephens's Translation, i, p. 60.)

POTTERY.

There is not an entire vessel in the collection, all of the specimens being fragments of variously shaped, coarse, red pottery, well baked, one or two pieces being glossy on the surface. (Figs. 1 and 2.) Nearly all of the ornamentation is produced by animal forms luted on. The most of these are monkey heads adorned with scrolled, circular, and fluted coronets, and by deeply incised lines, often forming very ingenious patterns. Others bear human faces, all grotesque, and the figures of mythological animals. (Figs. 3–7.) In one of them a W-shaped wreath or festoon is luted on the outside. (Fig. 8.) A fragment of the bottom of a cup or jar deserves especial mention, on account of the ingenious labyrinthine design traced on it by a deep furrowing, produced evidently by a sharp instrument when the vessel was soft. (Fig. 9.) This bold, deep tracing is characteristic of all the ornamentation on the

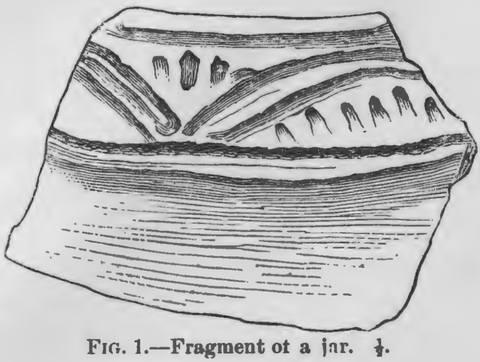

FIG. 1.—Fragment ot a jar. ½.

FIG. 4.—Handle from the edge of a dish. ½.

FIG. 5.—Handle from the side of a dish. ½.

FIG. 2.—Fragment of a shallow dish. ½.

FIG. 6.—Handle from the edge of a dish. ½.

FIG. 3.—Handle from the edge of a dish. ½.

FIG. 7.—Handle from the side of a dish. ½.

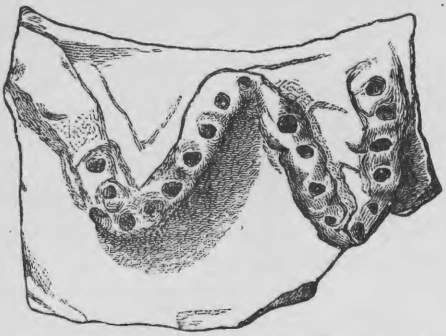

FIG. 8.—Fragment of pottery, with wreath luted on. $\frac{1}{2}$.

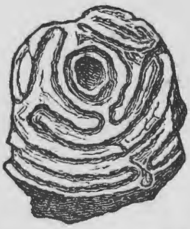

FIG. 9.—Bottom of a vase with the pattern traced in it. $\frac{1}{2}$.

FIG. 11.—Celt and handle of polished jadeite. $\frac{1}{5}$.

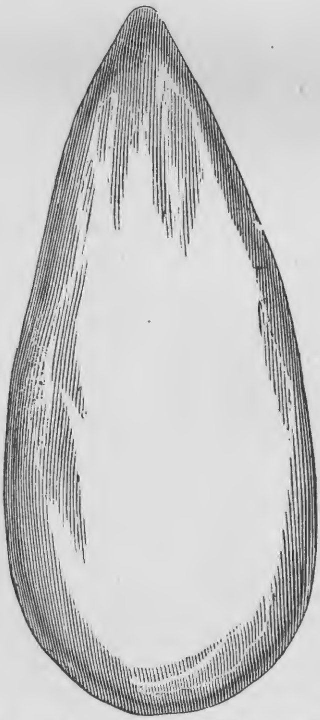

FIG. 10.—Polished, oval-sectioned celt. $\frac{1}{1}$.

FIG. 12.—Celt of jadeite in a handle of wood, Turk's Island. $\frac{1}{8}$.

pottery. Precisely similar fragments are in the National Museum from San Domingo, and, indeed, many of the pieces from southern Central America closely resemble them in quality and material.

CELTS.

The celts, one hundred and thirty-five in number, are of the very highest order of workmanship, being beautifully shaped, and many of them the most highly polished stone implements in the National Museum. The material is fine grained, and varies in color from black to nearly white, many of them being of a jadeite green. In shape, nearly all of them belong to Evans's third class, or oval-sectioned, and the great majority resemble his figure 75 so closely that I feel sure he is right in hesitating to believe the celt figured in his work to have been made in Scotland. (Fig. 10.)—(Evans, Stone Imp. p. 118. The use to which these polished celts was put, or, more correctly speaking, the manner of hafting them, is graphically illustrated in the accompanying sketch of a celt inserted in a mortise in a handle of hard red wood and found in a cave in Caicos or Turk's Island, by Mr. George J. Gibbs, and kindly lent by him to be cast and engraved. (Fig. 11.) A still more interesting and precious relic, from the same locality, and found by the same gentleman, is that given in figure 12, which represents a celt in the handle, the whole being gracefully carved out of a single piece of jadeite.

A beautiful ax, similarly carved from a single piece, is figured and described in Jones's Aboriginal Remains of Tennessee.—(Smithsonian Contributions, No. 259.)

Those interested in comparative archæology will take great pleasure in comparing these with figures 91, 92, and 93, of Evans's Ancient Stone Implements. This mode of hafting suggests that these oval-sectioned celts, set in their handles with the edge in a line with the haft, were rather battle-axes than industrial tools, although this is mere conjecture.

The celts in the Latimer collection vary in section from circular to oblong elliptical, in length from 1.75 to 12 inches, in width from .75 to 6.5 inches. The chord of the edge is often oblique to the axis of the stone. Some have almost semicircular edges; of others the edge is nearly a straight line. A few are so unique as to deserve especial mention. The figures in the margin represent, throughout this paper, the number of the specimen in the ethnological collection of the National Museum.

16893. A large, mottled, greenish, flat celt, pointed at the butt, fractured. Length 11.2, width 6.5, thickness 1.95 inches. Mr. Gibbs also sends drawings of two large flat celts, similar to this one and the three following, from Turk's and Caicos Islands. The occurrence of these large polished celts over so wide an area, corresponding in fact to that of the Caribs in Columbus's day, coupled with the frequent allusions of Herrera, Peter Martyr, and others to dug-out canoes, shaped like trays, and capable of holding from one to one hundred and fifty persons, leads us to a conjecture as to their use, and reminds us of the Indians of the northwest coast, where similar crafts are still made with stone implements. Some of the different methods of hafting are illustrated in Dr. Charles Rau's work on the archæological collection in the National Museum.—(Smithsonian Contributions, No. 287, Appendix.)

15899. A large, dark-bluish, flat celt, with the butt abruptly rounded and edged; that is to say, both ends are edged nearly alike. The sides are quite sharp and nearly parallel; length 9.34; width 5.5, and thickness 1.75 inches. Fig. 13.

16900. A dark slate-colored flat celt, pointed at the butt. Length 10.8, width 5.2, and thickness 1 inch.

16901. A reddish-brown flat celt, pointed at the butt. Length 9.5, width 5, thickness 1.55 inches.

There is a flat celt in the collection from Guiana, from which the foregoing large celts cannot be distinguished.

16978. A small, almost cylindrical, greenish-black celt, highly polished, and having two chisel edges, one at either end.

16965. A small polished celt, with the blade very much expanded at the edge.

16868. A dark reddish specimen, rough and pecked on the sides, as if to aid in hafting.

16974. A small and beautifully polished, nearly cylindrical celt, edged at both ends, but the edges are not in the same plane. (Fig. 14.)

16931. A dark-greenish celt, with flat sides, and the butt quite squarely truncated. (Fig. 15.)

16938. A flat-sided celt, somewhat resembling No. 16931.

16870. This specimen has a rough indentation around it, as if to aid in hafting.

8031 .A large, dark-red, hatchet-shaped, broad-edged celt, with a deep encircling groove, as if for a handle. This is the only stone celt or ax that furnishes a clear example of grooving for any purpose. (Fig. 16.)

17039. A flat paddle-shaped stone, grayish-white, the blade circular, the handle slender and tapering. (Fig. 17.)

SMOOTHING AND SHARPENING STONES.

It is to be understood, in speaking of these objects as smoothing-stones, that we do not know what they were used to smooth, or whether they were used for any such purpose. We use the name for convenience of classification, and shall readily change it as soon as their function is ascertained.

17034. A polished flat stone, subtriangular, one side being quite straight, the other flaring out near the base. The lower edge is slightly curved, about half an inch wide, and exceedingly smooth.

17035. This is very similar to the last named, but the sides are more symmetrical. (Fig. 18.)

FIG. 13.—Massive polished celt. Nearly $\frac{1}{2}$.

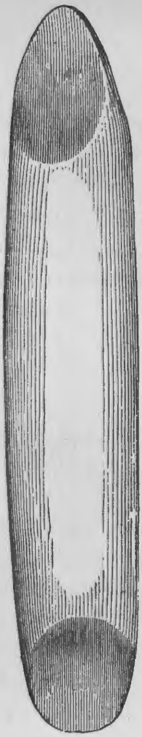

FIG. 14.—Two-edged polished celt. $\frac{1}{4}$.

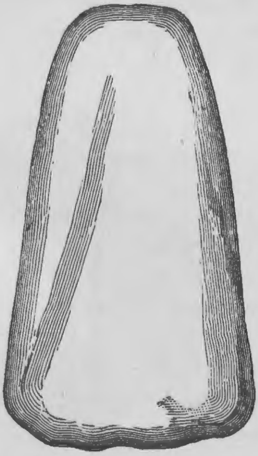

FIG. 15.—Flat-sided truncated celt. $\frac{1}{4}$.

FIG. 16.—Grooved celt. $\frac{1}{2}$.

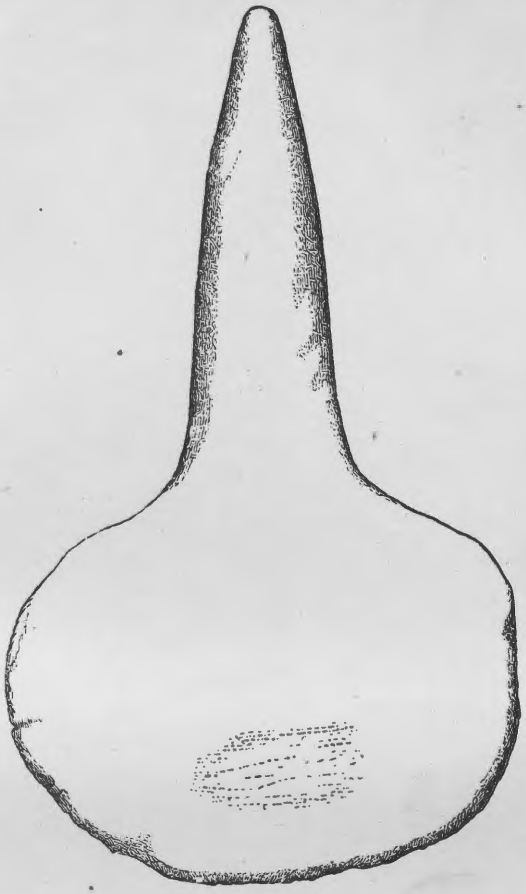

FIG. 17.—Paddle-shaped celt. ½

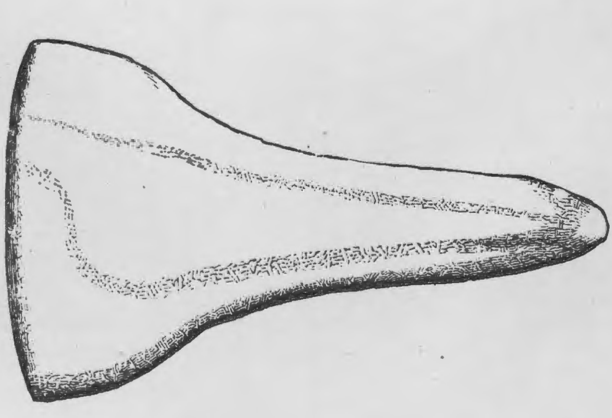

FIG. 18.—Smoothing-stone. ½.

FIG. 19.—Boot-shaped smoothing-stone. ½.

FIG 20.—Bell-shaped pestle.

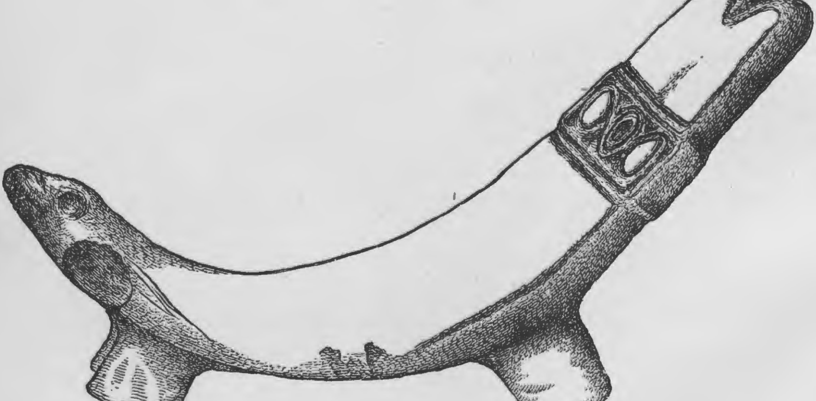

FIG. 21.—Animal-shaped stone stool. ⅛.

17036. Similar to the last two, but more triangular; the sides are scarcely curved.

17037. A somewhat pestle-shaped specimen, but twisted like a horn; the shaft is crooked, the lowest part bulbous, and the bottom tolerably smooth. Rougher than the foregoing.

17038. A boot-shaped specimen, the top bent forward and pointed, and the toe coiled upward. It is somewhat smooth on the sole. (Fig. 19.)

17055-'57. These are small slender stones, such as are called whetstones or sharpening stones by writers on stone implements.

MEALING IMPLEMENTS.

These will be treated of as the upper and the nether millstone, or simply as the upper and the lower stone. They are nearly or quite all of volcanic material, and resemble in shape and wear implements used for grinding various kinds of food in Central America. Some of the pestles still have a burnished, oily appearance on the lower end, as if caused by the preparation of chocolate, for which, probably, many of them were employed. The various vegetable substances used by the natives of the West Indies are given in Herrera, and are referred to frequently in Irving's Columbus. These stones are so characteristic of this region that I will describe each one briefly.

Upper stone.

17031. A short bell-shaped pestle, having a double ridge and an intervening furrow around the upper end.

17032. A rough bell-shaped pestle, with a rude human face on the top. Precisely similar ones are found in San Domingo, (Flint Chips, pp. 227, 230, 231;) but, in many cases, the human face is replaced by the head of an animal. (Fig. 20.)

17040. A light-yellowish stone, in the shape of a cross, probably a worn-out pestle. The top is notched.

17066. A small almost-cylindrical pestle.

17067. A conoid, oblong pestle.

17068. A very small conoid pestle, 1.5 in. in height.

17073. A napiform muller, side cylindrical; diameter 4 in., height 1.5 in.

17074. An oblong flat stone, resembling a muller, and having a groove all around the side like a hat-brush.

77110. A massive, light-colored, polished limestone pestle; the base is almost cylindrical, but the upper part is a four-sided prism.

Lower stone.

17061. A small, hemispherical, bowl-shaped mortar, with a swelling or prominence at one point on the rim.

17062. A small, oblong, dish-shaped mortar, deeply concave.

17063. A boat-shaped mortar or dish, sharp at each end, deeply concave. A very beautiful and unique specimen. Length 16.5 in., width 8.2 in., height 4.75 in.

17064. A semi-ovoid, deeply concave, tray-shaped mortar, 17 by 11 inches.

17065. Small cup-shaped mortar, similar to the paint mortars from the United States. Herrera repeatedly mentions the painting of their bodies black, white, and red by the Indians of the West Indies.

17077. A small four-legged metate, slightly dished in the middle, but flat-bottomed. This specimen resembles Fig. 8, on page 229 of Flint-Chips, and may have been a stool, the wavy elevated rim precluding the use of a muller, and a flat bottom rendering the use of a pestle quite improbable. I shall speak of this subject more fully a little further on.

17078. A massive three-legged metate, of a porous, dark, volcanic stone. It is slightly sagged and depressed on one edge, and elevated at one end. They have a backward slant, so as to resist the pressure of the person operating at the higher end. Length of slab 21 inches, width 14 inches.

17079. A massive three-legged metate, similar to the foregoing, but the surface is nearer a plane. The dimensions are the same.

STOOLS.

The single specimen under this head, (No. 17076,) Fig. 21, has been classed, hitherto, with metates. It is a thin and deeply-sagged slab of grayish sandstone, and stands on four short legs. At the less elevated end three projections are neatly carved to represent the head and fore-feet of a turtle. The eyes are deeply sunken as if for the insertion of pearls or jewels. The higher end is abruptly elevated about six inches, and is crossed by a band ornamented with a scroll which occurs with certain modifications on other objects. There is a decided warping or twist in the upper surface, the ornamentation of which, as suggested by Dr. Rau, renders the idea of its having been a metate doubtful. In Fig. 22 another view is given of the stool, which shows some of its characters to better advantage. The following quotation from Stephens's translation of Herrera (Herrera, Stephens's Translation, i, 55) fully establishes its use: "When the ship was ready to sail (from Cuba) the Spaniards returned on the 5th of November with three of the native Indians, saying they had traveled twenty-two leagues and found a village of fifty houses, and that they contained about 1,000 persons, because a whole generation lived in a house; and that the prime men came out to meet them, led them by the arms, and lodged them in one of the new houses, *causing them to sit down on seats made of a solid piece of wood in the shape of a beast with very short legs and the tail held up, the head before with eyes and ears of gold*, and that all the Indians sat about them on the ground." This object being of stone, there might still have been room

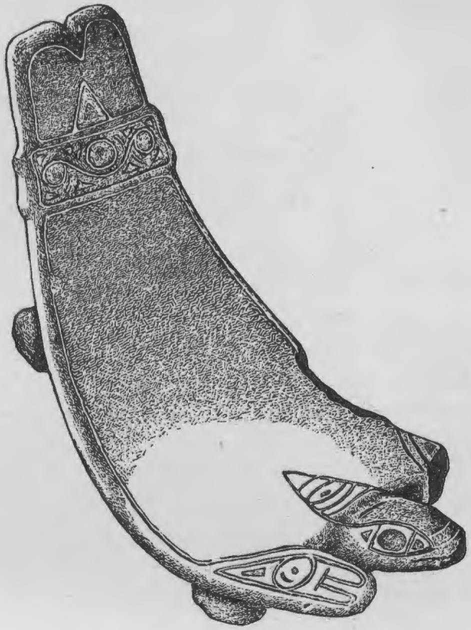

FIG. 22.—Upper view of Fig 21.

FIG. 23.—Wooden stool from a cave in Turk's and Caicos Islands. $\frac{1}{8}$.

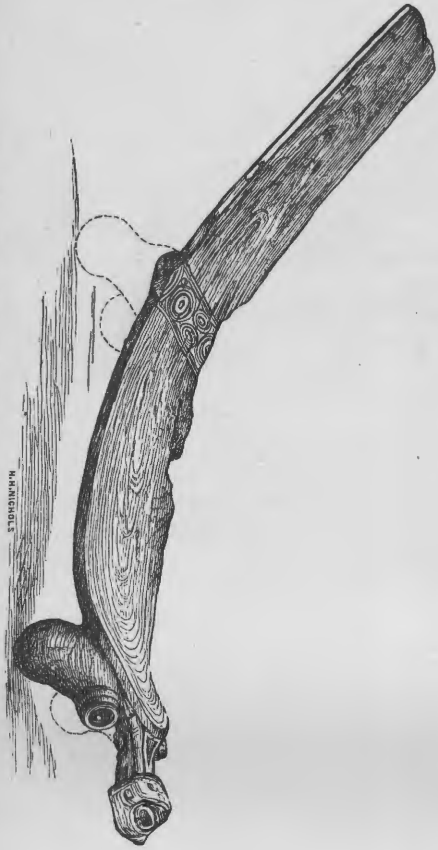

FIG. 24.—Wooden stool from Turk's and Caicos Islands. $\frac{1}{6}$

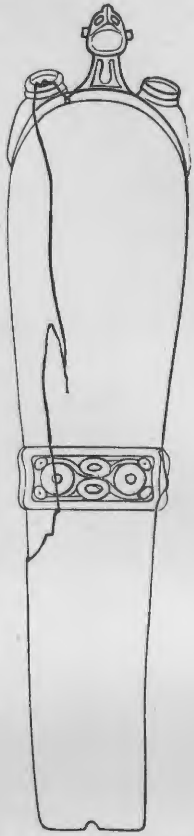

FIG. 25.—Upper view of Fig. 24 restored. $\frac{1}{6}$.

FIG. 26.—Ornament in relief on the upper part of Fig. 23. $\frac{1}{3}$.

FIG. 27.—Head-ornament of Fig. 24. $\frac{1}{3}$.

for doubt but for the timely arrival of confirmatory evidence while the engraving was being executed. Prof. William M. Gabb has sent to the National Museum, with the joint compliments of himself and Mr. D. R. Frith, of Turk's and Caicos Islands, two wooden stools, fac-similes of those spoken of in Herrera. (Figs. 23 and 24.) Fig. 25 is an attempt to restore Fig. 24, which has been mutilated, not by the tooth of time, but by the hatchet of the vandal. These objects are made of a very hard dark wood, and are just fitted to an ordinary man when reclining as in a hammock, from which the pattern of a stool is possibly derived. These two specimens were found in a cave. The stone stool described above is a fac-simile, except in size, of those sent by Professor Gabb, the scrolled ornamental band across the stone stool being represented in one of the wooden ones by an elaborate scroll-work in relief. The mathematical accuracy in this and other drawings is no exaggeration of the originals. In the wooden objects, as in the stone one, the eyes excavated for precious stones are plainly visible, but the jewels are wanting. (Figs. 26, 27, and 28.) Fig. 26 is the tail ornament of Fig. 23, and is somewhat effaced. Figs. 27 and 28 are the head ornament and scrolled band of Fig. 24. The use of these stools of state is frequently mentioned by the historians of the voyages of Columbus. (Irving's Columbus, i, 194, 234.) One of the provinces of Cuba paid tribute in them. (Stephens's Herrera, i, 63, 74.) Especial thanks are due to Professor Gabb and Mr. Frith for the timely opportunity of illustrating what was previously a rather dark text to me.

SPHEROIDAL AND DISCOIDAL STONES.

It is impossible to tell the uses to which these stones were put. It is something to know that they show signs of use, and testify that in the Antilles, as elsewhere in the world, nature has gently led her children by the hand, furnishing them with their simplest implements ready-made, and thereby imparting the first lessons of civilization.

17046. A small kidney-shaped pebble, with natural perforations.

17034. A small egg-shaped bowlder, similar to those used by the Dakota Indians in their flail-like war-clubs.

17058. A spindle-shaped pebble, covered with a deposit of iron. It seems to have been used in grinding paint.

17069. A spherical stone, diameter 3.6 inches.

17070. A similar stone, 2.75 inches in diameter.

17071. A rough spheroidal stone.

17072. A discoidal granite pebble.

17131. A massive spheroidal stone, diameters 8.95 and 10.2 inches. A small perforated disk of soft material like soapstone, and carved to resemble the spindle-whorls found in various countries is shown in Fig. 29.

BEADS.

17042. An oblong syenite bead, not perforated.

17043. A similar bead to the foregoing. The hole not coming out as designed, a second perforation was attempted. This is a fine specimen of perforation, 2.4 by 1 inch. (Fig. 30.)

17044. A small oblong bead, unfinished, showing the striæ of the preliminary grinding.

17053. A string of seventy small chalcedony beads, about the size of peas. They are quite perfectly rounded and perforated—some of them in two directions. This is the most remarkable sample of aboriginal stone polishing and drilling that has ever come under the observation of the writer. It is exceedingly doubtful whether another collection of so many witnesses to savage patience and skill has been found anywhere in one specimen. We are here reminded of the "eight hundred beads of a certain stone called ciba, given by Guacanagari to Columbus on his second voyage."

17059-'60. Slender cylinders of quartz, 5.5 by .6 inches.

AMULETS AND STONE IMAGES.

Very little is known of the religion of the Indians living on these islands. Herrera mentions that a sailor of Columbus reported the seeing of a man with a white tunic down to his feet on the island of Cuba, (Stephens's Herrera, i, 131,) and that an old Indian reported a cacique of a certain island who was clad like one of the Catholic priests. (Stephens's Herrera, i, 134.) Two chapters (Herrera, Dec. 1, Book iii, chap. 3, 4,) are devoted to the customs and worship of the Caribs, but little light shines from them upon our stone images. As in many other instances, an accurate description may prove to be the key of the enigma.

17047. A small lizard-like figure of a black slaty material. The head and tail are broken off; the feet are doubled against the body, represented as covered with scales. Frequent references are made to lizards and alligators in the old chronicles. (Fig. 31.)

17048, '49, and '50, Small kneeling figures made of white marble. The arms and legs are represented as pinioned back and the shoulder-blades are perforated for suspension. These and the two following seem to have been worn as amulets. (Fig. 32.)

17051. A small kneeling human figure, having the back of the neck perforated. The face is that of an animal, although it is somewhat mutilated and indistinct. (Fig. 33.)

17052. A small erect human figure of green jadelike material, perforated through the head from ear to ear. (Fig. 34.)

The inhabitants of Hispaniola, on the authority of Friar Roman, (Irving's Columbus, I, 390,) had small images of their gods which they bound about their foreheads when they went to battle.

The larger stone images or pillar-stones seem to be out of place, when ranged by the side of the elaborate polished objects. They are strikingly similar in rudeness and in general design to some brought from Central America by the Hon. E. G. Squier. The only feature that seems to rise above the most savage simplicity of design is the fact that in some of

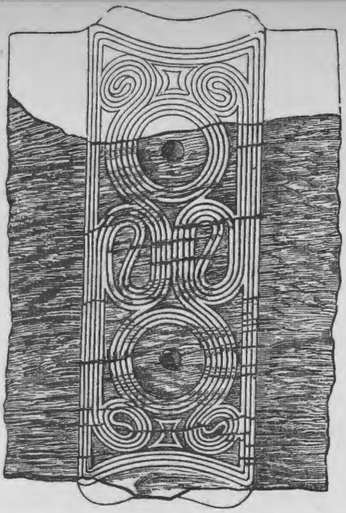

FIG. 28.—Scrolled ornament in relief of Fig. 24. $\frac{1}{8}$.

FIG. 29.—Disk-shaped carved stone. $\frac{3}{4}$.

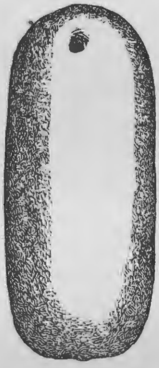

FIG. 30.—Perforated bead. $\frac{3}{4}$.

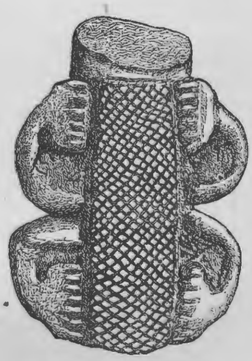

FIG. 31.—Lizard-shaped Amulet. $\frac{1}{1}$.

FIG. 32.—Amulet of marble. $\frac{3}{4}$.

FIG. 33.—Amulet. $\frac{3}{4}$.

FIG. 34.—Amulet of greenish stone. $\frac{1}{1}$.

those from both districts a human face is carved on the stomach of the human figure represented by the whole stone. According to Friar Roman, (quoted in Irving's Columbus, I, 390,) each cacique had a temple or house apart where an image of his Zemi, or tutelary deity, carved of wood or stone, or shaped of clay or cotton, generally in some monstrous form, was preserved.

17125. An irregular slab, having a rude face in relief on one side. Seven parallel lines extend from the chin downward, as if to imitate a beard; 16.1 by 7.5 inches.

17126. A fish-shaped bowlder, 28.5 inches long. On the narrow end is a sitting human figure, having the hands clasped under the chin and the feet doubled up with the soles together. On the stomach is a circle, seeming to have been designed to represent a human face.

17127. A boot-shaped slab, on the broad end of which is a rude human face, crowned with a chevroned band across the forehead.

17128. An irregular kite-shaped slab, bearing on one side a human face. On the right side of the face are two hieroglyphic marks, the one in the shape of a heart, and the other resembling a cleaver with two small furrows running from the edge. Now and then a heart-shaped stone implement turns up in our collection; but we are not to suppose that the American aborigines used this to symbolize the human heart itself or the domain of Cupid.

17129. A rude slab of yellow stone, 28.5 by 13 to 10 by 6 inches. On the flat face is a human figure very roughly furrowed out, bearing on its stomach an inverted face. On the top of the slab a circle is furrowed out. The carving on this and the foregoing slabs was apparently done by pecking out the depressions with stone chisels, leaving the eyebrows, nose, and lips in intaglio.

17132. An ingenious figure of a human female head and breasts in coral; the natural spheroidal swellings on the material forming the head and breasts.

17142. A stalactite bearing a rude carving of a human face.

17150. A fragment of a pillar-stone, the face of a man deeply carved in its surface.

17281. A rude pillar-stone, 41 inches in height, the upper part being a kneeling figure with its face upturned, its huge mouth open, and its hands clasped under the chin. Two circles are carved on the back.

MAMMIFORM STONES.

These strange and beautiful objects present, in more than one-half of the specimens, the image of a human figure lying on the stomach, with the face more or less upturned, the mouth open, and the countenance wearing a tortured look. The other end of the stone represents the lower extremities of the body, so doubled up as to expose the soles of the feet against the rump. On the back of the prostrate form is a conoid prominence, beautifully rounded up, straight or slightly concave in outline in front, a little convex in the rear, swelling out on one side slightly more than on the other, and descending more or less lower than the top of the head and of the rump so as to form anterior and posterior furrows. The whole appearance cannot fail to remind the student of the legend of Typhoeus killed by Jupiter with a flash of lightning, and buried beneath Mount Ætna. Though no one could use this resemblance as an argument in favor of early communication between the Greeks and the primitive people of Porto Rico, yet the Typhoean legend has been found in many lands, and it is quite possisible that a similar myth may have been devised in various places to account for volcanic or mountainous phenomena. The Antilles are all of volcanic origin, as the material of our stone implements plainly shows. I am indebted to Prof. S. F. Baird for the suggestion that, from the sea, the island of Porto Rico rises in an abrupt and symmetrical manner, highly suggestive of the mound in the mammiform stones, so that with the aid of a little imagination we may see in these objects the genius of Porto Rico in the figure of a man, a parrot, an alligator, an albatross, or some other animal precious in these regions where larger animals are not abundant, supporting the island on its back. The Typhoean figure undergoes many modifications in the series examined, and doubtless, if the specimens in other collections could be placed by the side of these, many more interesting results could be reached. The human face is often replaced by the head of a bird or of some other animal, but the feet when distinguishable are always human. The bottom of the stone is in striking contrast with the upper surface. While the latter is nearly always exquisitely polished, the former is always very rough, either from use or never having been finished. The bottom is sometimes flat, sometimes convex, but most frequently sagged up in the middle and hollowed out into a cymbiform cavity. In such cases the object rests unsteadily upon the chin and knees, the under side of which is polished by wear. In quite a number of them the prostrate man cannot be clearly made out, his head and lower extremities being presented by simple swellings or knobs. A variety of details is noticeable, which will appear in the following description of the objects, since I have been unable to find two precisely alike.

16980. A highly polished specimen of marble. There is a wide headband across the forehead of the figure, ornamented with chevrons and hemispherical cavities. The right side is the fuller, the bottom concave and rough, and the apex slightly battered. This battering is doubtless an accident, as none of the others exhibit it. Length 10.3, width 4.5, height 5.3 inches. (Fig. 35.)

16981. This specimen is of a light-bluish material. The head and breast of an albatross replace the human head. On either side of the breast and on either side of the front of the mamma is a cup-cutting. The furrows at the base of the mamma in the front and rear are wide and deep. The bottom is warped up and hollowed out. Length 11.95, width 4.5, and height 4.9 inches. (Fig. 36.)

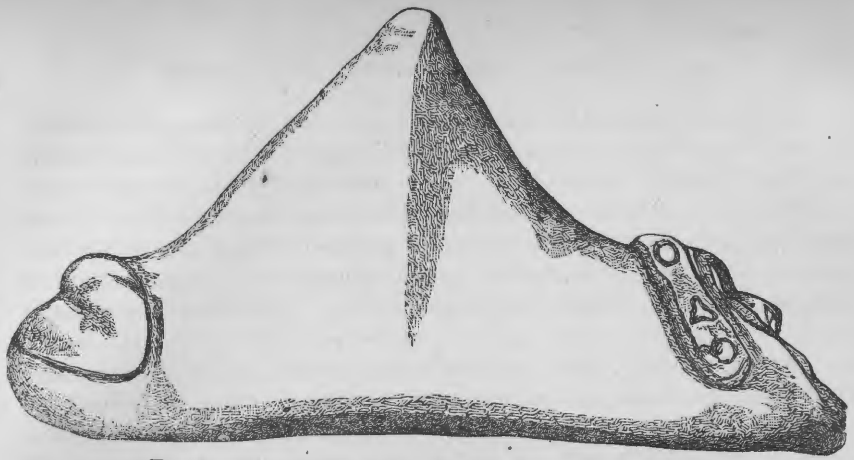

FIG. 35.—Mammiform stone, with human face. About $\frac{1}{4}$.

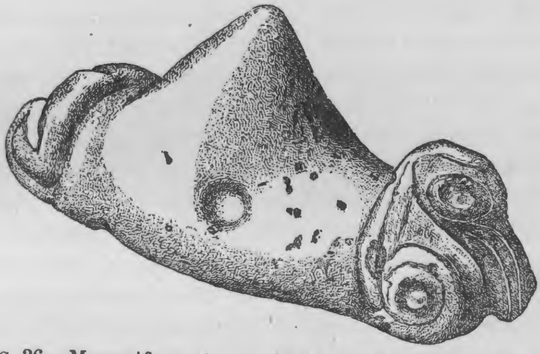

FIG. 36.—Mammiform stone, with the head of a sea-bird. $\frac{1}{4}$.

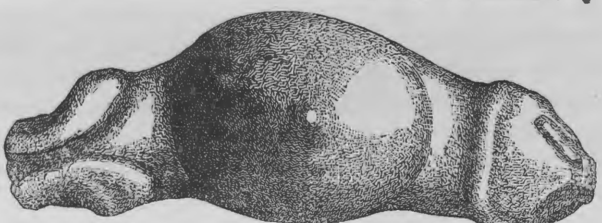

FIG. 37.—Mammiform stone, upper view, greatly warped. $\frac{1}{4}$.

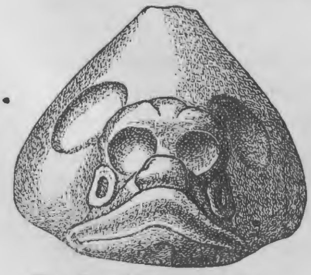

FIG. 38.—Mammiform stone, front view. $\frac{1}{3}$.

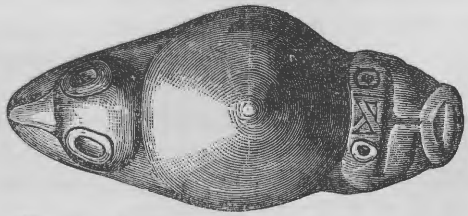

FIG. 39.—Mammiform stone, upper view. $\frac{1}{4}$.

16982. This specimen is of a dark volcanic material. The face and feet are both well turned up. The anterior and the posterior furrows are deep, the left side bulged out, and the bottom slightly hollowed. Length 11.6, width 4.3, and height 5.65 inches. (Fig. 37.)

16983. A rough specimen made of dark volcanic stone. The head and feet are close to the mamma, leaving very slight intervening furrows. The bottom is hollowed out. Length 7.3, width 3.6, and height 3.7 inches.

16984. A large specimen, made of white marble. Across the forehead is a chevroned band, the triangular spaces of the chevrons being filled with straight lines parallel to the lines of the chevron consecutively. The right side is fuller than the left, and the bottom slightly hollowed. Length 12.3, width 5.9, and height 6.35 inches.

16985. A dark volcanic stone, broken. The head has a high ridge running above the forehead, making a deep furrow between it and the mamma. The bottom is quite flat. Length 11.1, width 5.5, and height 7.7 inches.

16986. A rough specimen, made of volcanic stone. The face and feet are much flattened out, and the anterior and posterior furrow are broad and shallow. The left side is fuller than the right. The mamma is slightly winged, or angular, on the sides, front, and rear. The bottom is nearly flat, and very rough. Length 8, width 3 55, height 3.8 inches.

16987. A dark-colored specimen, of volcanic material. The head is grotesque and high-ridged, making the front furrow deep. Across the thighs is a chevroned band. The feet are twisted around so as to bring the toes against the rump. The right side is fuller than the left. The bottom is warped up and hollowed out. There are four shallow cylindrical depressions on the mamma on a level with the furrows, one on either side of the anterior and posterior portions. Length 11.65, width 4.6, height 4.05 inches. (Fig. 38.)

16989. A very smooth bluish-gray specimen. The head resembles that of a parrot, and there is a perforation through the beak. The thighs of the prostrate figure are ornamented with chevrons and dotted circles. The right side is fuller than the left, and the bottom elevated and hollowed out. Length 6.85, width 3, height 3 inches. Although this is a very smooth specimen, the different style of illustration adopted by the artist exaggerates this feature unduly, in comparison with others which are hatched in the engraving. (Fig. 39.)

16990. A polished specimen, made of mottled black and white marble. The head and posterior portion are very much flattened out, making the furrows long and shallow. The left side is fuller than the right, and the bottom is elevated nearly an inch, and hollowed out. Length 10.75, width 4.3, height 4.1 inches.

16991. A rough volcanic stone. The human figure is not visible in this specimen, the ends being simple knobs, between which and the base of the mamma there are slight furrows. The bottom is flat. If we were looking for the evolution of higher from lower forms, this stone would typify the lowest grade, or possibly the starting-point in the departure from a conical implement. Length 7.9, width 3.4, and height 4.2 inches.

16992. A light-bluish specimen. The head and feet are quite close to the mamma, making the furrows narrow and shallow. The right side is fuller than the left, and the bottom smooth. Length 8.2, width 4, height 4.45 inches.

16994. A dark, mottled, volcanic stone. The face has been very much battered by time. There is an elevated band across the forehead, making the furrows narrow and deep. The right side is fuller than the left, and the bottom elevated and hollowed out. Length 7.95, width 3.5, height 4 inches.

16695. A light-blue volcanic stone. The furrows are almost wanting, and, as in a specimen previously mentioned, the feet are reversed. The bottom is very roughly hollowed out. Length 5.6, width 2.4, height 3.6 inches.

16996. This specimen is made of yellowish white marble. The furrows are broad and shallow. The right side is fuller than the left, and the bottom hollow. The plane of the bottom is also twisted or warped, due probably to the original form of the stone. Length 10 8, width 4.6, height 4.55 inches.

16998. A dark volcanic specimen. The head-band abuts on the mamma, leaving a very slight furrow in front, but the posterior furrow is deeper. On the sides of the mamma are cup-cuttings. The bottom is elevated and hollow. Length, 6.15, width 3.2, height 2.7 inches.

17000. Of mottled marble. The head resembles that of a hog or peccary, but is grotesque. The feet are human; the furrows are broad and deep; the left side is fuller than the right, and the bottom is deeply hollowed. Length 12.55, width 5.5, and height 5.3 inches. (Fig. 40.)

17001. A smooth specimen, made of volcanic material. The furrows are broad and deep, the right side swelled out, and the bottom elevated and hollow. Length 8 55, width 4.15, height 4.4 inches.

17002. A rough specimen, made of marble. The furrows are narrow and shallow, the left side full, the bottom elevated and slightly hollowed. This specimen is much weather worn. Length 8.5, width 4, height 4.6 inches.

17003. A fine specimen, made of white marble. The face is well executed, the head-band being wide and ornamented with cup-cuttings and frets. The feet are broken off. Instead of a cymbiform cavity in the bottom, there is a deep cup-cutting, around the border of which is a perfectly circular furrow. This object has been battered by secondary use as a pestle. The dimensions are estimated. Length 12.8, width 4.4, height 3.75 inches.

17004. Of a rough volcanic material. The head resembles that of a hog or peccary. The furrows are deep. There are two deep cup-cuttings at the feet. The left side is full and the bottom elevated. Length 9.65, width 4.4, height 3.5 inches.

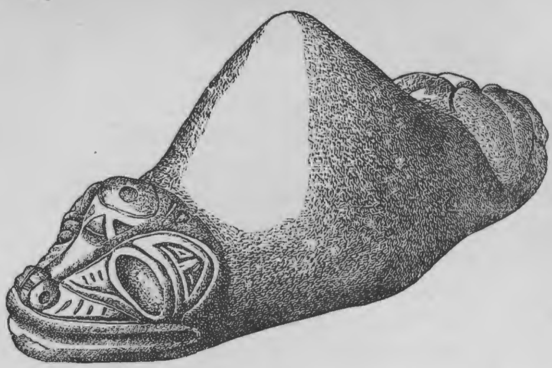

FIG. 40.—Mammiform stone, quarter view. ¼.

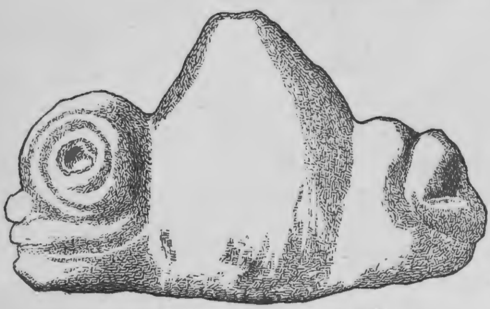

FIG. 41.—Mammiform stone with owl-shaped head. ½.

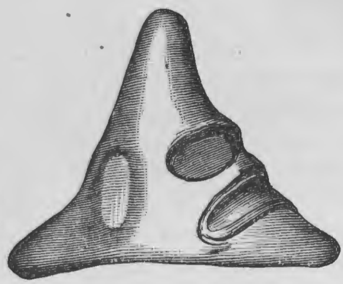

FIG. 42.—Highly-polished mammiform stone. ½.

FIG. 43.—Mammiform stone with frog-like ornament. ½.

FIG. 44.—Mammiform stone, with alligator head. ½.

FIG. 45.—Head of a mammiform stone, upper view. About ½.

FIG. 46.—Foot of a mammiform stone, upper view. ⅓.

17005. A dark specimen, of volcanic material. The head resembles that of an owl or parrot. The furrows are deep, the right side full, and the bottom flat. Length 4.95, width 2.9, height 2.95. (Fig. 41.)

17006. A dark specimen, of volcanic material. The head resembles that of a parrot. The furrows are broad and shallow. The left side is full, the bottom slightly elevated and hollow. Length 6.3, width 2.55, height 2.95 inches.

17007. A smooth reddish specimen, of volcanic material. The head is like that of a peccary. The furrows are wide and shallow, the left side full, and the bottom well elevated and deeply hollowed. Length 11.35, width 5.2, height 4.8 inches.

17008. A light-colored specimen, of volcanic material. The furrows are wide and deep, and the bottom hollow. The length 10.9, width 5.3, height 5.5 inches.

17009. A small mottled specimen, of dark volcanic stone. The face is slashed with deep lines. The furrows are deep, the right side full, and the bottom pecked in the middle and worn quite smooth at the ends. Length 5.8, width 2.1, height 2.2 inches.

17010. A highly polished specimen, made of a dark green stone, similar to the material of the most beautiful celts. The ends and top taper out finger-like. The human face is carved on the front of the mamma. The bottom is elevated and roughened, but not hollowed. This is a highly finished and unique specimen, departing quite widely from the typical form, and resembling no other in the collection. (Fig. 42.)

17011. A curious specimen, made of mottled flinty limestone. The projecting ends are entirely wanting. The front of the mamma or cone exhibits a grotesque human face. The rear is carved to represent a frog, whose nose forms the apex of the stone, and whose back and hind legs, drawn up, fill the remaining surface. The fore legs pass down the sides of the cheeks and under the lower jaw of the human face in front. This is truly a marvel of aboriginal art, and may be set down as the best specimen of this class in the collection. (Fig. 43.)

17012. A small specimen, of white marble. The grotesque head resembles that of an alligator. The feet, as usual, are human. The thighs are ornamented with chevrons and circles. The furrows are narrow and shallow, the left side full, the bottom unusually cymbiform. Length 4.85, width 2, height 2.75 inches. (Fig. 44.)

17013. A small smooth specimen, of yellowish marble. This is a very plain object, without carvings of any kind. Length 2.75, width 1.35, height 2.3 inches.

17014. A small rough specimen, of mottled volcanic material. The feet are broken off. The furrows are shallow, and the bottom hollowed out. Length 3.6, width 1.75, height 2.05 inches.

17015. Head of a mamiform stone, of volcanic material.

17017. The head of a mammiform stone, of white marble. The head-band is ornamented with chevrons and three cup-cuttings. This was undoubtedly a very beautiful implement. (Fig. 45.) The absence of duplicates in such a large collection is somewhat striking, and yet testifies to the richness of fancy in the artists. This figure, however, is almost identical in material, physiognomy, and the shape and ornamentation of the head-band, with the head of number 17003.

17018. The foot of a marble mammiform stone. The feet are finely expressed; indeed, they are the best-looking pair of feet in the whole lot. The thighs are ornamented with chevrons and cup-cuttings. This may have been the foot of the object to which the foregoing number was the head, or more probably to the broken specimen described as No. 17003. If not, it is a relic of a very finely wrought implement. (Fig. 46.)

MASKS.

It requires a slight stretch of the imagination to call the objects included in this class masks. The only ground upon which we do so is their resemblance to many of the false-faces or masks worn in pantomimes. These, of course, never could have had any such use. Three of them are somewhat similar to the objects just described. The bottoms are hollowed out, there are furrowed depressions at the base of the prominence, and the mammiform elevation is grotesquely observed, being replaced by a face, the Aztek nose forming the apex of the stone. The Typhoean figure is sometimes present.

17988. Mask of gray volcanic material. The head and foot are simple knobs. The forehead and cheeks are furrowed and the bottom elevated and very hollowed. Length 8.65, width 4.8, height 6.25 inches. (Fig. 47.)

17993. Mask of mottled volcanic stone. The ends are simply rounded and the bottom hollow.

16997. Mask of a reddish-brown volcanic stone. The prostrate man is present, the mouth of the mask being toward his head.

Five of the masks, 17020, 17021, 17023, 17024, 17025, are more or less grotesque human faces, with cleat-like projections on the back, scarcely admitting of a doubt that they were designed for fastening to a handle or pole. (Fig. 48.) Indeed, if we were allowed to follow up the clew, these cleat-like projections might throw much light upon the furrows found at the base of the mammæ of the mammiform stones, hinting that these, too, might have served in some way or other as insignia or club-heads. But where all is conjecture we shall have to possess our souls in patience.

Three of the masks, 17029, 17030, 17031, are flat kite-shaped stones with the human face carved partly in relief on one side. (Fig. 49.) The following table gives the dimensions in inches and decimals·

17029. Length 5.1, width 4.15, thickness 2 inches.

17030. Length 7, width 4.45, thickness 1.85 inches.

17031. Length 5.9, width 3.75, thickness 1.35 inches.

There is one mask, discoidal in form, from the periphery of which two

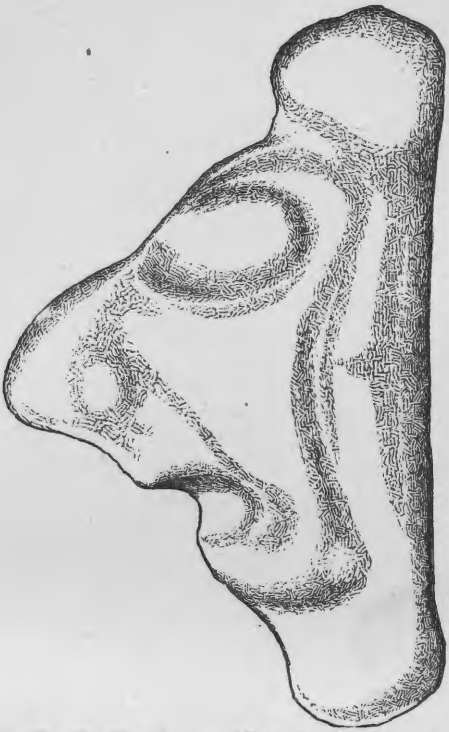

FIG. 47.—Profile of mammiform mask. About ½.

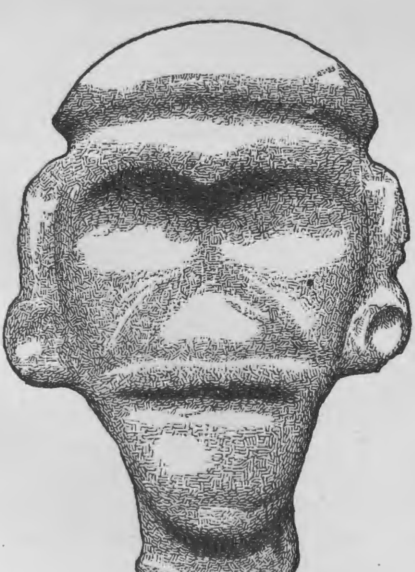

FIG. 48.—Mask with projections for attachment. ½.

FIG. 49.—Flat kite-shaped mask. ½.

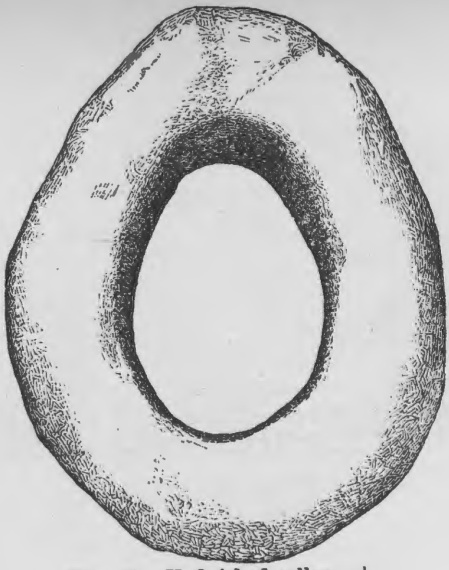

FIG. 50.—Unfinished collar. $\frac{1}{8}$.

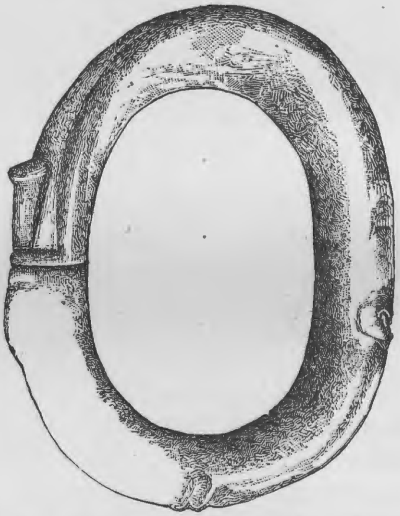

FIG. 51.—Right-shouldered massive collar. $\frac{1}{8}$.

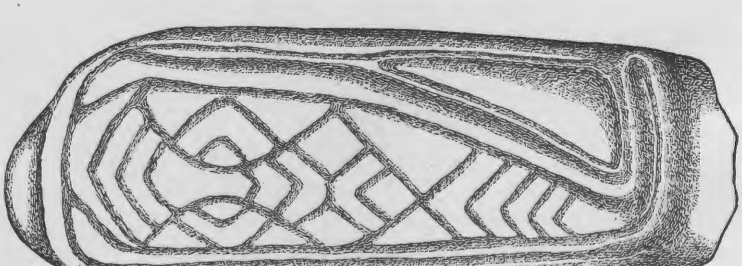

FIG. 52.—Gourd-shaped panel of a massive collar, with its ornament. $\frac{1}{2}$.

cylindrical knobs proceed, looking, again, very much like attachments for a handle. 17022 is a very rude mask of marble.

COLLARS.

The objects commonly called collars receive their name from their resemblance to horse-collars, and not from any knowledge we have of their use. There were thirty-five of them in the Latimer collection, but some were exchanged and sent away before this description was written. Four of them are yet in the rough state—so rough, in fact, that we cannot positively affirm that they were destined for collars, (Fig. 50.) None of the characteristic marks of the collars are visible. Assuming this as their probable end, they serve to show what an immense amount of labor it must have taken to reduce a stone of such great size and hardness to the slender and graceful finished object. The accompanying table gives their dimensions in inches:

Number.	External length.	Internal length.	External width.	Internal width.	Height or thickness.
17100	19	9.5	15.3	7	4.5
17101	20.8	10.2	16.9	7	5.5
17102	23.35	8.4	17.7	7.3	5.8
17103	20	11	17	6.5	3.9

Of those that are finished there are two classes—the massive oval, and the slender oblique-ovate, or pear-shaped collars. The latter are far more highly polished and ornamented than the former, and some of the ornamental patterns on the massive forms are reproduced but more elaborated on the slender variety, notably the gourd-shaped ridge surrounding the panels. One of these objects is figured in "Flint-Chips," p. 231, but it is either wrongly drawn or represents another class entirely different from any in the Latimer collection. Another is said to be engraved in Mem. de la Soc. du Nord, containing Mr. C. Rafn's report on the "Cabinet d'Antiquitées Américaines à Copenhagen, 1858," but I have not seen it. In Scribner's Monthly, August, 1875, are four woodcuts of collars pretty faithfully drawn. Both classes are marked by the presence of a projection or prominence resembling a knot on the outside of the upper limb of the circumference. This projection, always midway between the anterior and the posterior margin, is sometimes on the right side and sometimes on the left. This circumstance gives rise to two subclasses, the right-shouldered and the left-shouldered. The other marks which, by their peculiar forms, or by their presence or absence, give individuality to the different specimens are: the shoulder; the shoulder-ridge, or fillet; the boss, or swelling at the bottom; the right panel; the left panel; the panel ornament (always most elaborate on the side opposite the shoulder); the marginal prominences of the shouldered side; the panel border, or scroll; and the marginal ridge and furrow. The marks will be better understood by the accompanying figures 51, 53, 55, 59. The material of which they are all made is a volcanic stone of different color and texture.

1. *Right-shouldered massive collars.*

17104. The shoulder resembles closely a knot of a tree, and about six inches below there is another swelling as though the knot entering above came out at this point. There is no transverse ridge beneath the shoulder. The right panel is a plain moon-shaped chamfer pecked on the stone. The left panel is a gourd-shaped space inclosed in a bead-like ridge, and has its wide end extending quite around the bottom of the collar to the chamfer so as to form a quasi-boss.

17107. The shoulder of this one is inverted bell-shaped. The shoulder ridge is a transverse swelling. The right panel is a parallel-sided chamfer. The left panel is gourd-shaped and ornamented with herring-bone furrows. The bottom of the collar is very much enlarged by the lower margin of this gourd-shaped panel. (Fig. 51.)

17108. The shoulder is bell-shaped, and beneath it is a narrow transverse ridge uniting at its extremities with the marginal ridges, which extend quite around the upper half of the collar. The right panel is an oval chamfer. The left panel is gourd-shaped, and is ornamented with lozenges, chevrons, and triangles, prettily designed to fill up the space. (Fig. 52.) This is an exquisite specimen of design and execution, and as well as many others already examined, and to be examined, indicates marked progress in the division of labor.

17109. The shoulder is a mere swelling, without any definite outline, and the shoulder ridge is wanting altogether. The right panel is a slight chamfer, the left panel a deep-furrowed triple chevron. A rather plain object.

2. *Left-shouldered massive collars.*

17105. The shoulder of this collar is a mere swelling out, as it were, of the stone. The shoulder-ridge is likewise a transverse elevation beneath the shoulder. The left panel is a parallel-sided chamfer extending from this transverse swelling quite to the bottom of the collar, where it is bounded by a transverse ridge or quasi-boss. The right panel is the gourd-shaped pattern ornamented by an oblong spiral ridge. The gourd pattern in this and other massive collars reappears in the slender variety, where it is represented by a somewhat quadrilateral panel having a looped ridge extending beyond the anterior margin.

SLENDER OBLIQUE-OVATE COLLARS.

The slender collars, which compose the greater part of the set, are more highly elaborated in every respect than the others, and differ from them so much in weight and finish as to suggest a difference or function. (Figs. 53, 55, 59.) Where so little is known concerning them, however, this is more than we can affirm.

FIG. 53.—Right-shouldered slender collar. $\frac{1}{6}$.

FIG. 55.—Right-shouldered slender collar. $\frac{1}{6}$.

FIG. 54.—Left panel, panel-ornament, panel-border, and boss of a right-shouldered slender collar. About $\frac{1}{2}$.

FIG. 56.—Left panel of a right-shouldered slender collar, with its ornaments. $\frac{1}{2}$.

1. *Right-shouldered slender collars.*

8029. (Fig. 53.) The shoulder is distinctly bell-shaped, having a pecked chamfer on its outward portion. The transverse shoulder-ridge is quite prominent. The right or plain panel is inclosed in a quadrilateral ridge which bears on the middle of its anterior and posterior sides a very marked swelling. This is a constant feature on the anterior and posterior margins of the panel on the shouldered side, whenever this panel is present. The face of the panel is indented with an oval depression or cup-cutting. The left panel is bounded by a border-ridge, and ornamented by a large ring in the center, on either side of which a human leg drawn up is represented. (Fig. 54.) The anterior margin of this panel, which I have called the panel border, is a double scroll.

8030½. The shoulder is well expressed and the shoulder-ridge wide. The right panel is enclosed in a broad ridge with the swellings on the margins, and has a plain center. The left panel is inclosed in a double ridge and furrow looped and perforated at its upper anterior corner. This is also quite plain, although the double scroll is found on the margin. This and the foregoing specimen were given to the National Museum some years ago.

17080. (Fig. 55.) The shoulder is bell-shaped, and the encircling shoulder-ridge abuts upon the shoulder so that no line separates them. The right panel is inclosed within a ridge with the swellings, and has an oval cavity pecked deeply into its central space. The left panel is inclosed by a ridge with the loop in its upper anterior corner, and is ornamented by an elaborate winged sun-pattern. (Fig. 56.) The panel border is a wide scroll.

17085. The shoulder is quite prominent, its upper circular face rolled outward. The transverse shoulder-ridge is carried all the way around the stone. The right panel is inclosed by a ridge with the prominences, and is rough-pecked over its interior space. The left panel is inclosed by a ridge, and was formerly well ornamented, but it is now nearly worn off, whether by use or time I cannot say. The panel border is a delicate double scroll, having two of the volutes perforated. The boss, which in most of the slender collars is an immense swelling, oblique to the plane of the stone, is in this specimen rolled out like a pouting lip.

17087. The shoulder is bell-shaped. The transverse shoulder-ridge borders three sides of the shoulder—that is, it turns up along the margins of the collar. The right panel has the ridge and prominences but no ornament. The left panel is inclosed in a ridge looped on the upper anterior margin. The panel border is slightly scrolled, but much worn. The boss is ridged up on the inside of the specimen.

17088. The shoulder is a mere swelling with a slight transverse ridge, The prominences are present on the ridge of the right panel, which is ornamented with a shallow oval depression. There is no ornament on the left panel. This is a very plain specimen and rudely polished.

17089. The shoulder is bell-shaped, and the shoulder-ridge passes quite around the stone. The right panel is inclosed within a ridge with the prominences; its ornament is an oval depression whose edges are slightly in relief. The left panel is inclosed in a looped ridge, and is without ornament. The upper transverse portions of the panel-ridges encircle the stone as in Fig. 55.

17091. The shoulder is bell-shaped and grooved. The right panel has the prominences and oval depression. The left panel is wanting.

17092. Shoulder bell-shaped, and the transverse ridge beneath it encircles the stone. The right panel having the marginal prominences is roughened on its face and ornamented with a ring and dot. The left panel is much worn. The panel border is a double scroll. The boss and upper transverse panel-ridges encircle the stone.

17099. (2). A fragment containing boss and panels. The right panel with the marginal prominences and oblong oval depression. The left panel has a perforation in the marginal loop of the inclosing ridge.

2. *Left-shouldered slender collars.*

8028. The shoulder a slight rough swelling, without the subjacent transverse ridge. The left panel has the marginal prominences and a double chamfer on its face. The right panel is wanting, a simple transverse ridge marking the upper extremity, from which the stone gradually expands toward the boss.

8030. The shoulder is bell-shaped and well rolled out. The transverse shoulder-ridge is wanting, but the furrows on either side of the shoulder converge gradually, and give the appearance of the overlapping of the two ends of a hoop. The left panel is inclosed in a double ridge with the marginal prominences and is ornamented with a deep oval depression. The right panel is inclosed in a ridge with a perforated loop on its upper anterior margin, and is ornamented with chevrons, whose triangular spaces are filled with incised lines parallel to the sides of the chevron consecutively. The panel border is a double scroll with a small human face represented between the scrolls. It has been said that the human face is not seen on the collars. This is the only exception in this collection if the fragment to be mentioned next is not a portion of a collar. (Fig. 57.)

17026. A fragment containing the boss and a part of a right panel. The panel ornament is a large-featured human face. The end of this fragment is notched and perforated, as if for secondary use. (Fig. 58.) I am not positive about this fragment. If it is not a portion of a collar, it is a class by itself; and if it is, it is not like any other in the class as represented by the Latimer collection. Two objects somewhat similar are engraved in Scribner's Magazine for August, 1875, but as I have not seen the originals I cannot speak with certainty as to the resemblance between it and them.

17081. The shoulder is bell-shaped, and hollow on the top. The

FIG. 57.—Right panel of a left-shouldered slender collar. $\frac{1}{3}$.

FIG. 58.—Supposed boss and panel of a slender collar. $\frac{1}{2}$.

FIG. 59.—A left-shouldered slender collar, showing the shoulder-swelling, the boss, and the panel-border. $\frac{1}{6}$.

FIG. 60.—Right panel and scrolled border of a left-shouldered slender collar. $\frac{1}{3}$.

shoulder-ridge encircles the stone. The left panel has the marginal prominences and the oval depression. The right panel is ornamented with lozenges and triangles surrounding a circular depression in the center. The boss and the transverse panel-ridges encircle the collar.

17082. (Fig. 59.) The shoulder is well set off from the stone, and is subtended by a very shallow ridge. The left panel has the marginal prominences and oval depression. The right panel is inclosed in a ridge looped at the upper anterior corner, which is continued to form a part of the panel marginal scroll. The panel is ornamented with a dotted circle at each end, inclosed in a sigmoid ridge, the ends of which expand gracefully to fill the triangular spaces between the sigmoid, the circles, and the border-ridge of the panel. (Fig. 60.) The boss is ridged up on the inside.

17083. The shoulder is bell-shaped, having its transverse ridge nearly encircling. The left panel has the prominences and oval depression. There is no right panel. The lower end of the specimen is roughly pecked.

17084. The shoulder is not very prominent and is continuous with the transverse ridge. The left panel with its prominences very plainly executed. The right panel is a smooth space inclosed in a ridge which runs into the boss at the lower corners.

17086. The shoulder well rounded out and winged on the margins, the shoulder-ridge abutting on the shoulder and encircling the stone. The left panel has the prominences and a small oval depression. The right panel is inclosed in a double ridge and furrow, and ornamented with chevrons and parallel included lines. The panel-border is an elaborate double scroll, with triglyphs in the center of each.

17094. The shoulder slight and flattened, and abutting on the shoulder-ridge. The left panel has the prominences and a slight oval depression. The right panel is a looped ridge ornamented with lozenges and triangles. The panel-border is a double scroll with small triglyphs. The boss is ridged on the inside.

17095. The shoulder is bell-shaped, and subtended by a wide and encircling shoulder-ridge. The left panel has the prominences, and an oval chamfer in the center. The right panel included in a looped and perforated ridge is plain in the center. The panel-border is an elaborate double scroll. The transverse panel-ridges and boss encircle the stone, and the furrows of the panels are repeated on the inside of the collar. A truly unique and beautiful specimen.

17096. The shoulder is very slight, and has its transverse ridge encircling. The left panel has the prominences and oval depression. The right panel is an unornamented surface inclosed in a double ridge and furrow. The transverse panel-ridges and boss encircle the stone.

17098. The shoulder is slight and much flattened, and is subtended by a narrow shoulder-ridge. The left panel has the marginal prominences and a chamfered interior space. The right panel is wanting and the boss small. This is a very rude specimen.

17099. (1.) A fragment of a collar. The left panel is present and has the marginal prominences and a smooth interior surface. A short portion of the right panel remaining indicates a plain surface inclosed in a ridge looped on the upper anterior corner.

17099. (2.) A fragment of a collar, consisting of a boss and a left panel, the latter with the prominences and a deep oval depression.

17106. The shoulder is bell-shaped, with cup-cuttings on its sides. The shoulder-ridge is extended upward along the margins of the shoulder on either side, and thence quite around to the upper transverse ridge of the right panel. The left panel has the prominences, and its interior space smooth. The right panel is smooth and inclosed in a ridge looped at the upper anterior corner. The panel-border is a double scroll fretted on the sides with cup-cuttings in the volutes. This is somewhat transitional in form between the massive and the slender.

Dimensions of the collars in inches.

Number.	External length.	External width.	Thickness at the top.	Thickness at the right.	Thickness at the left.	Thickness at the bottom.	Depth at the top.	Depth at the bottom.
17104	17.5	14	2.15	2.2	2.1	2.3	4	4
17107	17.5	14	2.3	3.15	2.5	2.55	4	4
17108	17	13	2.45	2.45	2.45	2.3	3.8	3.8
17109	18	14.5	2.8	3.1	2.7	3.3	5	5
17105	17.75	15	1.7	1.7	2.2	2.9	4	4
8029	18.1	11.4	1.4	1.4	1.35	3.3	1.75	3.6
8030½	17.5	12	1.35	1.5	1.4	2.95	1.5	3.1
17080	13	11	1.25	1.55	1.25	3.25	1.7	3.7
17085	18	12.5	1.15	2.1	1.35	3.55	1.9	3.5
17087	17.5	13	1.45	1.9	1.45	3.45	2	3.1
17088	16.8	11.1	1.25	1.55	1.45	3.8	1.8	3.75
17089	16	11.2	1.4	1.45	1.4	2.45	1.6	2.9
17091	17	11.5	1.3	1.55	1.3	2.9	1.7	3.5
17092	18.7	12.2	1.45	1.55	1.5	3.1	2	4.05
17097	15.9	11.6	1.35	1.45	1.45	2.05	1.7	2.65
17099(3)	....	....	....	....	....	3.55	....	3.8
8028	18.4	12.3	1.4	1.4	1.5	3.6	1.65	3.15
8030	17.6	11.5	1.2	1.35	1.5	3.5	1.65	3.3
17026	....	....	....	....	....	4.25	....	3.8
17081	17	12	1.4	1.5	1.5	2.9	1.8	2.9
17082	17.2	11	1.5	1.25	1.35	2.85	1.95	3.25
17083	17	11	1.2	1.3	1.35	2.9	1.7	3.2
17084	16.4	11.4	1.1	1.3	1.65	2.85	1.6	3.2
17086	17.5	11.7	1.25	1.2	1.7	3.2	1.7	3.3
17094	15.9	10.7	1.2	1.25	1.35	2.85	1.7	3.5
17095	17.95	12	1.4	1.45	1.6	3.8	1.8	4
17096	16.1	10.9	1.15	1.2	1.35	3.35	1.8	3.3
17098	17.1	11.45	1.5	1.5	1.75	2.15	2.2	2.95
17099(1)	....	....	....	....	....	3.45	....	3.15
17099(2)	....	....	....	....	....	2.75	....	3.45
17106	18	13	1.7	1.7	2.05	2.95	3	4.5

CONCLUSION.

The objects which I have described are all from Porto Rico, and, together with a collection of interesting antiquities from other parts of the world, which do not come under my province, were bequeathed to the Smithsonian Institution by Mr. George Latimer. This generous benefactor of the Institution was of an English family who migrated to

America in 1736. His father was a merchant in Philadelphia, where his son George was born in 1803. Having often visited the West Indies as a supercargo, he became attached to the country, and, in 1828, entered the mercantile commission business in St. Thomas. He afterward removed to Saint John's, Porto Rico, where he remained until near the time of his death, which occurred in Paris August 2, 1874, from the effects of a surgical operation. He was an honored citizen, and for many years was consul-general of the United States for the island. He was, at the time of his death, consul for Holland and Austria, and had been created by the King of Spain a "Knight of the Order of Isabella." Mr. Latimer has left no written descriptions of the objects and the localities of their discovery. His nephew, Mr. W. H. Latimer, writes: "I believe he was prompted in the beginning by curiosity, but with increase of materials and knowledge of the subject came also a greatly increased interest, that spared neither pains nor expense in the augmentation of his treasures. Visiting personally any neighborhood where his labors were likely to be rewarded, and calling to his assistance many others in different parts of the island, he added constantly to a collection which he highly prized as the only one of importance existing of the aborigines of the island. Some of the specimens were found in caves, but the greater part were turned up by the plow and hoe, when new lands were put under cultivation, but I cannot specially localize them or say whether any were found in graves or in shell-heaps."

According to Sir John Lubbock's classification, the makers of these objects were a purely neolithic people, and, according to Mr. Morgan, they were not savages, but were in the "middle status of barbarism." In addition to the fruits of nature, they prepared maize and cassava and fermented drinks. They lived in round and square houses, with thatched roofs, grouped in small and large villages. They made pottery, the boldness and truthfulness of whose ornamentation attest their division of labor. In a warm climate very little clothing was needed, yet they spun and wove cotton cloth. Their implements of industry, so far as we have recovered them, are, I repeat, the most beautiful in the world. Their canoes, especially in Porto Rico, were exquisitely wrought, with the sides raised with canes, daubed over with bitumen, and not flat, but with a keel. (Stephens's Herrera, i, 340.) Their pastimes were the diversions practiced by our own Indians, consisting principally of mock fights, in which oftimes many were wounded or killed. Their artists were prodigies in design and workmanship, as the finer forms which I have described attest. Their social life is little understood, but probably resembled in all respects that of the Florida Indians at the time of the discovery. The absence of all flaked or chipped stone implements may be accounted for in several ways. The siliceous rocks which take the finest chipping are not found here, and in many of the islands shell (*Strombus gigas*) is the only available material for any implement. Neither are the large animals here which require such hard and fine points for their destruction, nor sharp knives and scrapers to cut them up and to tan their hides, which would be useless for clothing in this climate if they had them. In the second place, many of the woods are extremely hard, and with charring take a very fine point or edge, sufficient to pierce or cut fish, birds, or men. We are not to lay too much stress, therefore, upon the absence of rude stone implements, especially as the collections from these parts are as yet very meager. Still it is quite possible that the civilization of the Caribs and of their hereditary enemies was introduced from the mainland, and the absence of chipped and flaked tools, if further demonstrated, will be sufficient evidence of this.

As to the place of most of these objects in an anthropological museum we are sufficiently informed, but concerning the use of the masks, the mammiform stones, and the collars, we are entirely in the dark. Some of these rare objects are figured and described in Flint-Chips, with references to Latham, Wilson, to Cherminier and Guesde's collection from Guadeloupe at the Paris Exposition, to Schomburgk, Poey, and Cato, (Flint-Chips, pp. 223–240.) I have seen but cannot recall the title of an account of the Copenhagen Museum by Valdemar Schmidt, in which one or two figures are given. In Scribner's Monthly for August, 1875, Dr. J. B. Holder figures and describes a collection in the American Museum in Central Park, New York.

As to whether they were the work of the Caribs and of their more peaceful neighbors there may be a difference of opinion. The fact that the peculiar forms here enumerated are found throughout the ancient Carib area; that the stone seats resemble in form and ornamentation those made of wood and used by persons of distinction mentioned by the early historians of Columbus's voyages, and recently discovered by Messrs. Gabb and Frith; that the celts are like those used in Polynesia and on the northwest coast of America, where large dug-out canoes are still in use; all these lend great force to the opinion that these are Carib or Arawak implements, and not the relics of an older civilization driven out by them. However, my own mind is very far from a positive opinion on this point.

Some suggestions of possible function arise in the mind concerning these doubtful forms, when we come to handle a great number of them. The rough under-surface of the mammiform stones suggests the grinding of paint, incense, spice, or some other precious material, and the natives are said by the historians to have been fond of aromatic substances. Against this it may be urged that they are too costly for mortars; that some are hollowed underneath, some are flat, and some are convex; and that though very rough on the under side, the roughness seems to be that of an original pecking, excepting at the chin and knees of the Typhoean figure, where the stone is worn smooth. The furrows at the base of the mammæ seem to indicate the custom of lashing them to a staff as ensigns, or to dash out the brains of a victim or an enemy. There is no mention, however, so far as I am acquainted, of the natives performing human sacrifices. This lashing theory is strengthened by the fact that on some of the masks which closely resemble the mammiform stones there are cleat-like projections, evidently to be lashed to a handle. There are no grooves worn in the furrows by a lashing that I could discover. The bulging to one side of the mammæ, some to the right, others to the left, hints at their use in pairs. Their elegance of design and variety of execution in conformity with an ideal, characterize these as the highest type of sculpture with stone implements in the world.

The collars are quite as puzzling. Their right and left shouldering, and the more exquisite finish of the panel opposite the shoulder, when the panel is present, seem to prove that they were to be used in pairs. Their gradation in ornament, the presence or absence and the form of certain conventional parts, seem to speak of distinctions of some kind. Some very interesting indications of the manner in which humanity has elaborated its culture, guided by the leading-strings of nature, are given in the course and construction of the ridges and furrows which constitute the ornaments of the panels and the marginal ornaments. There are no sharp and deep corners, but the furrows wind about in curves returning into themselves, or run out into some deeper furrow, simply because a man working with a stone tool cannot make a sharp and deep corner. Some of the designs on these panels and marginal ornaments are very ingenious, as may be seen by the patterns given in Figs. 52, 54, 56, 57, and 60. The same characteristic is noticeable in the scroll-work of the wooden tools, and in Fig. 43. Such is the form of these relics of an extinct race; but whether they were the regalia of sacrificial victims, of military heroes, of ecclesiastical worthies, or of members of some privileged caste, who marched in double file through the streets of Porto Rican villages long since decayed, will perhaps forever remain a mystery. (Stephens's Herrera, i, 62.)

One of the objects of this perhaps too detailed description will be accomplished, if the light thrown upon this neolithic people by the Latimer collection shall guide some future explorer among their antiquities, if haply he may be able to decipher their meaning.

THE PREHISTORIC ANTIQUITIES OF HUNGARY.

AN ADDRESS DELIVERED BY PROF. F. F. ROMER AT THE OPENING OF THE INTERNATIONAL ANTHROPOLOGICAL CONGRESS, HELD AT BUDAPEST, SEPTEMBER, 1876.

From the *Matériaux pour L'Histoire Primitive et Naturelle de l'Homme.*—Translated for the Smithsonian Institution by Charles Rau.

In addressing you for the purpose of considering the two allied sciences—anthropology and archæology—upon which the labors of this congress will be based, I can hardly overcome a feeling of embarrassment. You doubtless expect that, in my position as secretary-general, I should unroll before you a picture of what Hungary has done for those sciences, since most of you never have visited our country, nor have read the Hungarian works treating of them.

Here, as in Europe generally, it was almost considered a disgrace to pay attention to the barbarous nations, so far as their history before and after the great migrations is concerned. Only the study of the classical archæology of the Greeks and Romans was in vogue. Prior to the day when prehistoric archæology became a universal science, no one cared for the forms and decorations of the weapons, utensils, and trinkets of the so-called barbarous populations, but, in most cases, only for the precious materials of which they were made. The cemeteries and the tumuli, with their contents as simple and primitive as the men who used them, were, without any criticism, attributed to the great Roman people, even in parts of the country where the Romans never had been. The defensive works of prehistoric times, such as trenches, ramparts, and castles, were ascribed to them, and even on our geographical maps of that period one can see these works marked as Roman trenches, Roman fortifications, &c. In the catalogues of the National Museum, likewise, the arms, utensils, and ornaments of the barbarians have been assigned to the Romans.

Hungary has not had, like other countries, official archæologists appointed to attend to the preservation of the discovered objects. Only foreign savants, who in past centuries paid attention to such matters, have written on the antiquities of this country; and it must be stated that they spoke of them in a manner betokening the utmost simplicity of conception. Thus, they have affirmed in serious discourses held before academies, that gold grows naturally in the vineyards of Tokay, because there have been found in that locality objects made of gold wire, which presented no longer their original shape, having been altered and distorted by roots growing on the same spots. The bones of mammoths were at that time taken for those of giants, nummulites passed for grain, porous basalt for petrified bread, &c.

It is no matter of surprise, therefore, that during that period the country people paid no attention whatever to the relics they constantly met almost everywhere, and sometimes in enormous quantities, while cultivating the ground. In plowing up our ancient cemeteries, repeatedly and at various depths, they have destroyed the funeral urns; but neither their fragments and contents nor the skeletons discovered in the more regular burying-places excited their curiosity or tempted them to closer examinations. When they found articles of bronze they sold them like old iron or applied them to their own use, after they had been transformed by the blacksmith according to their notions. How many objects have thus been lost which would have served to elucidate the condition of an unknown people that has passed away long ago!

Our predecessors only collected flint articles, which they broke into pieces of proper size to be used for striking fire. The stone axes or "thunderbolts," to which they attributed in their superstitious minds the virtue of curing various diseases of men and beasts, were likewise preserved by them, and the myths attached to these implements are here the same as in other parts of Europe. Wherever people speak of thunderbolts the superstitions to which they have given rise are so inveterate and general, and the belief in their supposed powers appears so firmly rooted, that no stronger proofs of their high antiquity could be adduced.

This is all I can say concerning the opinions which the objects pertaining to remote prehistoric ages have elicited among our compatriots, even in the present century!

What has been done within the last forty years, since the brothers Augustus and Francis de Kubinyi and my distinguished predecessor, Mr. John Erdy, commenced the study of our antiquities, was communicated by me to the congress at Paris in my sketch of the prehistoric times of Hungary, in which I have summed up from memory, and in a very succinct manner, all that relates to this epoch.* To this I have only very little to add at present.

Prior to the Universal Exposition at Paris, in 1867, several of our foreign colleagues had visited our archæological museum. They fully appreciated our articles of bronze and precious metals, which then almost exclusively constituted our prehistoric collections. The museums of the neighboring countries were not ahead of us in that respect, considering that the study of classical archæology prevailed everywhere at that period. Nothing was bought or exhibited but choice specimens of classical antiquity, or such as were made of precious metals, and their number sufficed to satisfy the interest of the curious.

The resources of the National Museum being very limited, most of the specimens were the gifts of good patriots, and they were deposited without order or system, occupying the places assigned to them by the generous donors.

A new era for these studies and for our collections dates from the in-

* See Compte-rendu de la II[e] Session à Paris, p. 321, etc.

auguration of constitutional government in Hungary. The members of the diet, convinced that much was still needed to raise us to the level of the nations who had preceded us in the cultivation of prehistoric archæology, were judicious and patriotic enough to vote the sums requisite not only for the purchase of classical objects, for putting our collections in better order and cataloguing them, but also for the acquisition of specimens illustrative of prehistoric archæology and for explorations in the interest of that science.

It is very remarkable that the new development of the kingdom coincided with the Paris Exposition, where a retrospective section for the study of industries reaching back to the remotest times was, for the first time, added to the objects representing the achievements in modern art and ingenuity. It cannot be denied that the large number of specimens of stone, clay, bone, bronze, &c., exhibited on that occasion, excited the desire to collect analogous objects in our own country, and the labors of the International Anthropological Congress, then in session at Paris, served to strengthen this resolution. Thence arose new ideas and new plans for enlarging the scope of our National Museum. After the Universal Exhibition at Paris, the spacious hall, hitherto exclusively used for exhibiting the numismatic collection, was provided with glass cases, which already contain a remarkable collection ; a large portion, however, embracing new acquisitions and interesting fragments had to be deposited in drawers. When this congress is over, the new additions, which are quite numerous, will be placed in an adjoining hall. They chiefly comprise objects of stone, the number of which increases very rapidly.

I had the pleasure of showing at the Paris congress the first obsidian nucleus obtained from Transylvania. Until then objects of obsidian were generally thought to be of Mexican origin, because none from other countries were known, excepting a few found in Italy. This discovery was followed by another. I found in the mineralogical cabinet of our museum a much larger nucleus, and later I was really surprised to discover in the museum of the college of Debreczin our largest obsidian nuclei, which had all been collected in the neighborhood of the celebrated mountain of Tokay, where obsidian occurs in considerable quantities. Farther east the objects and fragments of obsidian become more and more scarce. We are now able to prepare a map showing our obsidian finds, which are already numerous and increase from day to day. This map will be made more perfect after the congress, and will assist in engendering in our country a higher appreciation of all that our honored guests deem worthy of their attention. But our obsidian flakes are by no means equivalent to those of flint, so frequently met in the north and west of Europe; and without attempting to ascribe to them a too remote antiquity, we will simply state that they often occur associated with objects of bronze, as proved by the discoveries made by the counselor of mines, Mr. Henry Wolf, on the island of Bodrog

(Bodrogköz.) The conchoidal fracture of our obsidian is more curved than in the Mexican mineral; our knives are usually not so long and straight, our arrow-heads less elegant and regular than those made of transatlantic obsidian or of Danish flint. The occurrence of large nuclei, from which the last flakes suitable for knives have not been detached, may be owing to the fragility of obsidian implements, which induced the head of the tribe or the family to preserve these nuclei, in order to have the material for the fabrication of knives and arrow-heads always on hand.

The implements of which we have spoken were for a long time the only ones found in Hungary. It was a general belief that no chipped flints existed in our country, because none of them had anywhere been noticed. Yet this supposition arose solely from the ignorance of the value of the objects, and from the want of a word to specify them. Our peasants found them frequently and called them "fire-stones," (*pierres à feu.*) When this indicative word had been discovered, and, moreover, when specimens of chipped flint had been sent from Denmark to some of our friends of archæology, attention was aroused, and chipped flints, and even nuclei, were found in several counties. In a few years, I am confident, we shall be cognizant of their existence in all parts of the country where siliceous materials occur, and hence our museums may be gradually enriched with such specimens, just as our improvised exposition was increased by the knives from the extensive collection of Miss Torma. So great has been our progress in securing and interpreting objects of chipped flint, which were still very rare, and much sought for, some months ago.

At present a new field of studies opens before us, and we shall soon have to relinquish the erroneous, but widely diffused, idea that during the epochs when stone played everywhere such an important part, Hungary was not yet inhabited on account of being covered by the waters of the sea.

Up to this day we know only a few well-authenticated celts of polshed flint. One of them was found in the county of Szabolcs, the others in that of Liptó; yet how many more will be discovered when we have learned to look for them, and when our peasants have been made acquainted with their value. As for other polished stone implements, we possess chiefly objects of serpentine, not only in considerable number, but also of very elegant appearance. This is sufficiently demonstrated by the old specimens of the National Museum, as well as by the late acquisitions of Baron Eugene Nyári, the Rev. Canon Francis Ebenhöch, the Rev. Vicar Stephen Mihàldy, and by the material which our compatriots, who take pride in showing you their best and most interesting pieces, have put here on exhibition. Yet all these interesting objects were neither looked at nor preserved prior to the successful researches made throughout the kingdom.

You behold, however, only isolated specimens; for it was not feasible to deprive the museums of their entire collections; and the private persons who were desirous of contributing their share in rendering the exposition more perfect had to abstain from sending all their objects, considering that the corridors of the National Museum, which alone were at our disposal, are already too narrow for a really complete exhibition representing the entire kingdom.

Objects of stag-horn and bone occur in prodigious number in some counties, more especially among the remains of repasts, and they are fashioned with a degree of skill which could only be acquired by long practice in the leisure hours of savage life. One may see, for instance, at Magyarad, at Szihalom, at Tószeg, at Szelevény, and at Csépa, objects of deer-horn and bone by the hundred and thousand, while articles of bronze and iron are but singly and sporadically met in these localities.

Our characteristic bronze articles are known throughout Europe: it has been sufficiently demonstrated that they are distinguished by peculiar forms. The numerous utensils, weapons, and ornaments of bronze bear witness that the Danubian countries had a civilization of their own, a fact becoming still more apparent by the quantity of the raw material and the number and size of the objects of copper. Is it necessary, gentlemen, to recall to your memory that these very articles of bronze and copper induced you at Stockholm to choose the capital of Hungary as the place of meeting for this year?

It is known that among semi-savage and warlike nations the nobility indulges in an excessive love of show. Their horsemen carry nearly all their treasure on their persons and horses, and hence they exhibit an extravagant taste in their offensive and defensive weapons, as well as in their armlets, fibulæ, necklaces, diadems, and horse-trappings, all of which are profusely embellished with spirals, with bells of different forms, with pendants presenting the shape of funnels, &c. Certain tubes, often overloaded with the ornaments peculiar to our districts, also should be mentioned.

In addition to the weapons and ornaments, there are utensils of copper and bronze, designed for digging the ground, for felling trees, and for cutting crops and brushwood. You will further see the metallic raw material, numerous fragments collected for being melted, ingots, molds, and unfinished objects, all of which are indicative of work performed *in loco*. Indeed, hearths for melting metals are not rare in our country.*

* During the fourth session of the congress, September 7, Mr. De Pulsky spoke of a *copper age*, which, he thinks, can be traced in Hungary. He believes that many implements in the National Museum, which are supposed to pertain to the age of bronze, consist in reality of copper. Nine of those instruments having been analyzed, it was found that they contain no trace of tin. Some consisted of pure copper, corresponding to the native copper of Hungary; others contained a little silver, like certain copper ores found in the same country. The implements in question most frequently resemble either the hatchets of woodcutters or the pickaxes still used by miners. These forms differ, according to Mr. De Pulsky, from the types characteristic of the bronze age, and

And as for fabrics of clay, are there anywhere found vases of this epoch which show more finish, more elaborate ornamentation and stranger shapes than those of ancient Pannonia? Or are there in other parts such quantities of those cones and pyramids of clay, hitherto considered as weights used in weaving? They probably also served as supports for cooking-vessels, considering that they are often blackened by smoke, and, moreover, have been met amid ashes and charcoal. Some of our vessels exhibit forms so singular and extraordinary that their application thus far has not been explained. The small vases and other diminutive objects in the rich collection of my friend, Baron Eugene Nyári, deserve our special attention, the more so since nearly all of them have been obtained from the same place, namely, his family estate at Pilin. Who can decide whether these miniatures constituted toys for children or were symbolic in character? Perhaps they represent on a small scale objects too costly to be abandoned forever.

The almost unique clay stamps, showing a variety of tasteful patterns,* and the small terra-cottas, representing animals, mostly sheep, oxen, and hogs, leave much room for speculation concerning their uses, especially when found with the remains of repasts.

Among the articles indubitably made in the country, we often meet products of the industry and art of remote regions, as, for instance, pearls from the Indian Ocean, beads of unwrought or polished amber from the Baltic Sea, and others of cut glass, which must have been derived from more civilized nations. These last-named relics betoken a commerce with the coasts of far-distant countries, and the character of their occurrence proves that they were family hoards brought together during a long lapse of time.

Those pagan monuments, the gigantic embankments and ditches disposed in two or even three parallel lines, which are met throughout the kingdom, inform us that it was once inhabited by warlike and quite numerous tribes, or by valiant proprietors who kept their large herds within immense and inaccessible inclosures. The power of these ancient

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hence he concludes that an age of copper, forming the transition from polished stone to bronze, must be claimed for Hungary.

This view, however, was not shared by Mr. John Evans. He observed that among the two hundred objects thought to consist of copper, only nine or ten had been analyzed. Yet if they were all composed of copper, there would be no sufficient ground for establishing a copper age. If such an age had existed, its types would resemble more the forms of the stone age than those of the bronze period. The pierced copper implements of Hungary certainly bear an analogy to a certain class of drilled stone articles; but the latter, Mr. Evans thinks, are referable to the bronze age rather than to the times during which stone was exclusively used. He concludes that the Hungarian copper tools belong to the bronze age, but were made in moments when tin—a metal not found in Hungary—could not be obtained.—[*Translator.*]

* To judge from wood-engravings, kindly sent by Professor Romer, these relics resemble the stamps which the Mexicans used for impressing ornamental marks on their cotton cloth. They also employed stamps in decorating their vases before they were baked.—[*Translator.*]

people, and their association in secure places of habitation of great extent, can furthermore be inferred from the enormous tumuli which one sees scattered widely apart over the country, and which, for this reason, have been considered as lookouts for sentinels, or as hills upon which the Turkish viziers pitched their tents; for our people ascribe everything of a strange character to the Turks. Yet these mounds, so different in construction and character, stood originally by the side of villages or camps, amid large forests which no longer exist. Even in our time mounds are met in the primeval forests, from Bakony to Százhalom, near Bakonybél, at Tátika, and in other extensive timbered regions of our country.

Arriving at the period of iron, that which lies nearest to our own time, it must be confessed that our relics composed of that metal are less numerous than those of bronze and even of stone, although these latter belong to more remote times. This fact will not surprise you when you learn that until now objects of iron have been totally neglected. Being in most cases corroded by rust and broken, and resembling, moreover, very often the implements of the present time, they were generally undervalued, not only by the common people, but also by the more instructed, who chiefly prize objects composed of precious metals, especially when they are well preserved and present elegant and extraordinary forms. Thus it has been until now; but in future these underrated relics, which are of such importance in their bearing on archæological questions, will be carefully collected and preserved.

This is all we can say in reference to our progress in archæological studies.

As for *anthropology*, it must be confessed that this science has not been cultivated among us to the extent it deserves. We have not yet a noticeable collection, and those of our savants who pursue that study must exert themselves, in order to keep pace with the anthropologists of other countries. We expect much, however, from the intimate intercourse that will spring up during this congress.

In general we may state, without self-praise, that for several years the interest of our countrymen has been increasing. Archæological publications are dispersed throughout our literature; museums multiply in the counties in a manner highly satisfactory to the friends of our science. I find everywhere *collectors* of antiquities, and the taste for original research is growing, as can be inferred from our improvised exposition. Thus we are entitled to the hope that henceforward our compatriots will preserve what they find, and that we shall soon possess all the material required for our studies.

It is true, we have no megalithic monuments; we cannot show you kitchen-middens or lacustrine habitations. They are either wanting in our country, or, if they exist, have not yet been discovered. On the other hand, we can place before you all that has come to light in our country within these last years. The liberality of our museums and the noble patriotism of our colleagues enable me, I am happy to state, to fulfill the promise given you at Stockholm, namely, to gather in our National Museum all or nearly all objects scattered over Hungary that might serve to facilitate the study of our bronze age, the most interesting task before us. What I promised two years ago is now an accomplished fact. It is left to you, honored colleagues, to discuss the important question to what people or peoples we are indebted for the objects which characterize so strikingly the development of our country.

I have prepared a table indicating the number of relics and the materials composing them. Our exposition embraces nearly 31,500 objects, of which 22,000 belong to the museums and private persons of this country, and 9,000 to the National Museum.

This total comprises—

Objects of ordinary stone, flint, and obsidian	9,400
Objects of polished stone	2,800
Objects of stag-horn	560
Objects of bone	1,600
Objects of clay	3,300
Objects of copper	190
Objects of bronze	7,630
Weapons	1,170
Trinkets and objects of gold and silver	1,800

From the composition of this table, and its incompleteness, it may be inferred that there are yet great gaps, and that the necessary minuteness is still wanting. Finally we shall obtain definite results, and the science will be cultivated among us as in other countries of Europe. In fact, we have had no time for preparing ourselves as thoroughly as we might have wished. Most of the works of our compatriots, written in the Hungarian language, arrived so late that it was not possible to translate them in time to be submitted to the congress; but as you doubtless desire to acquaint yourselves with the character of the studies pursued in our country relative to its antiquities, and as our own interest imposes upon us the duty of giving you full information, we shall present a complete *résumé* in our forthcoming report, which will reflect our labors like a true mirror.

JADE.

A HISTORICAL, ARCHÆOLOGICAL, AND LITERARY STUDY OF THE MINERAL CALLED YU BY THE CHINESE.

By S. Blondel, *of Paris*.

[Translated by Dr. E. Foreman.]

If among mineral substances there is any one which particularly deserves attention, it is jade. For a long time cabinets of mineralogy possessed this precious material in only humble specimens, acquired, however, at very high prices; but now, owing to closer relations between western nations and those of the extreme east, Chinese antiquities have become less rare, new and important collections of them have been formed, and the museums of Europe have been enriched with the most splendid works of art and pieces of the choicest quality. We therefore believe that it would be useful to oriental archæology to publish this memoir on jade, a mineral so highly valued by amateurs, and one whose curious history is so little known.

The jade, so common in the Indies and in China, as we all know, varies between a greasy white, or the color of old ivory, and a deep olive-green color, depending on the oxides of iron and of chrome which enter into its composition. Of all the various pebbles it is the hardest and heaviest, being fine-grained and compact in texture. Its polish, at the same time that it is attractive, always exhibits to the eye and sense of touch a greasy sensation, giving the appearance of inspissated oil or of wax. Although its more ordinary color is some shade of green, the classical variety is of a milky whiteness and nearly opalescent. In this case its limpidity, its fine texture, and tenacity are so great, that to the hand of the workman it feels as if glazed, qualities which make it sought after for the execution of valuable works. Pale green jade is likewise often used for cutting vases of every form and those ornamented with elegant reliefs. Its shade of color is uniform and agreeable, and it has a close, fine grain, susceptible of a high polish. Some pieces, having molecular peculiarities and a cloudiness which gives the stone a dull tarnished aspect, are employed in making vases of large dimensions, or even bracelets. Jade is sometimes even black, but not on that account much undervalued; it is sometimes clouded, and specimens are seen which recall the crystalline watering sometimes seen on tin or zinc which have been acted on by dilute acids. "But," says M. Albert Jacquemart, "of all kinds the two most rare are the orange jade, of which examples are known in Europe, and the imperial jade, a gem beyond price, worthy of being ranked with the finest emerald when of a fine green, and which, of variegated green and white, produces an effect superior to the richest agates. Ancient authors likewise speak of specimens of a citron yellow, deep blue, turquoise blue, and red. If it be, as the eminent English mineralogist, Kidd, supposes, that such varieties have really existed, their localities are exhausted or lost.

As regards the orange jade, M. Jacquemart hesitates about recognizing it, and refers to a sale-catalogue, where a vase, supposed to be made of it, is stated to be an oriental sardonyx of an amber-yellow color.

The old oriental travelers believed jade to be a variety either of marble or of agate. Abel Remusat, in a curious dissertation, supposes the jade to be the celebrated stone *Kasch*, or the ancient jasper, which has been, in all ages, brought from the Himmalaya Mountains into Asiatic countries. Theophrastus, who was learned in minerals, unites jasper and emerald under one species. Dionysius Periegetes describes it as a green transparent substance, comparing it with air and water for translucency, all of which is rather applicable to *aqua-marine*, although his commentator, Eustathius, calls attention to the word used by Dionysius. The pseudo Orpheus, of whom we have an apocryphal poem on precious stones, probably alluded to this kind of jasper when he speaks of it as the color of spring; which can bear no other interpretation than of a green tint. Finally, Dioscorides says positively that certain jaspers bear a resemblance to emeralds, others to a crystal, the *Callais*, which is a stone of a pale green or sea-green hue. Pliny, the naturalist, affirms that jasper is of the color of the emerald, and that it is worn as an amulet in all eastern countries.

The separation of jade and jasper into different species is somewhat modern, as M. Clement Mullet judiciously remarks; that it was effected only about 1647, when the third edition of Boetius was published, for it is seen in the treatise of Jean de Laet d'Anvers, concerning gems and stones, at the end of the volume, that jade is treated of as jasper. Now, however, the two minerals are regarded as entirely distinct. Jade is a silicate of alumina and lime, and jasper is a variety of quartz.

The white variety, called oriental jade, is the hardest of all. It melts when in fragments without any flux, and is readily fused. Chemical analysis presents the following composition:

Silex	50.50
Magnesia	31.00
Alumina	10.00
Oxide of iron	5.50
Water	2.75
Oxide of chrome	5.00
Lime	2.00

The specific gravity of the principal varieties, according to M. Damour:

White oriental jade	2.969
Grayish jade	3.003
Dull green jade	3.017
Jadeite, grayish-white, and of pearly aspect	3.344
Jadeite, bluish-gray variety	3.336
Jadeite, emerald-green, or imperial jade	3.338

One of the principal beds of this mineral, known in China by the name of Yu, is found at Tai-Thong, in the province of Chenn-si. The larger part, however, comes from the city of Khotan, in the canton of Yarkande, of ancient Chinese Turkistan, and is brought from Tartary through Bokhara. In that country there are entire mountains composed of it, and the purest pieces, precious for their beauty as for the fineness of grain, are found in the seams of the highest pinnacles. It is said that the mountain Mirdjai, in the principality of Khotan, is entirely formed of jade. The mineral presents itself in various localities, but the finest specimens are obtained from the very summit; a workman, provided with the requisite tools, climbs the rocks, detaches small masses, which roll down to the base.

It is impossible to explain the etymology of the word Yu. The only statement to be made with any confidence is that the word is of the highest antiquity. According to Abel Remusat, it is found in the LiKi, chapter phrengi, in that part of chi-king or book of verses entitled Ta-ya, and also in Yih-King, or book of transformations, at the definition of the hexagramme Ting. We close these remarks of the learned orientalist by saying that Chou-King, or Book of the Annals, indicated by the words Ta-yu and Y-yu the rarer as well as the more common jades.

The high prices brought by jades even in China has caused a kind of chalcedony to be much sought after, called by Bridgman, in his Chinese Chrestomathy, chalcedony-chrysoprase, and which the shrewd Canton merchants sell to foreigners for the true jade. There are two kinds ot it. One, of a feeble green color, is called fi-tsoui-yo or fi-pi-yu, and is brought from Yunan. The price appreciates as the color is more lively and of a more chatoyant apple-green tint. The other variety is a deep clouded green, and is known by the name hi-lai-kao-yo or hi-le-tchao-yu. It is brought from Kansouh.

From the earliest times the Chinese have attached a high value to jade. The Li-Ki, or Memorial of Rites, a canonical book in the Celestial Empire, in which the yu is compared to the subtile matter composing a rainbow concreted and fixed in the form of a stone, gives a proof of its venerable antiquity. The philosopher Koung-fou-tseu, (Confucius,) who lived five hundred years before our era, explained to one of his disciples why this stone, endowed with extraordinary qualities, possessed in ancient times the merit of being the subject of the meditations of sages and to be the symbol of virtue. One day the disciple Tze-kun inquired of his divine master, "May I dare ask you why the sages esteem the jade, and hold in light reverence the stone huen? Is it because the jade is very rare and the other stone quite common?" Koung-fou-tseu replied, "It is not because the mineral huen is abundant nor because the jade is scarce that the latter is valued, but because from all time the sages have compared virtue to jade. In their eyes the polish and brilliant hues of jade represent virtue and humanity. Its perfect compactness and extreme hardness indicate exactness of statement; its angles or corners, which are not incisive, however sharp they seem, are emblematic of justice; the pearl-like jades, suspended from the hat or the girdle as if falling, represent ceremony and politeness; the pure sound which it emits when struck, and which suddenly stops, figures music; as it is impossible for the ugly shades of color to obscure the handsome ones, or for the fine colors to cover up the poor ones, so loyalty is prefigured; the cracks which exist in the interior of the stone, and can be seen from the outside, are figurative of sincerity; its iridescent luster, similar to that of the rainbow, is symbolic of the permanent; its wonderful substance, extracted from mountains or from rivers, represents the earth; when cut as knei or as chon, without other embellishment, it indicates virtue; and the high value attached to it by the whole world, without exception, is figurative of truth." The Chi-King, or book of verses, says in confirmation of these analogies, "When I meditate on that wise man, his thoughts appear to me like the jade;" whence the value affixed by him to this gem.

As we shall have occasion to notice, the Chinese are firmly convinced that jade possesses many physical properties, which, according to the Chou-wen of Hin-chin, may be reduced to these: The yu is a very hard stone, unchangeable, sonorous, difficult to work, and possessing a soft luster. The author of Pe-hou-thong adds further that when dried at the fire it loses nothing of its weight, and is not any heavier by being moistened. For this unchanging quality it is that the sage was right in his estimate.

Modern Chinese partake with their ancestors a passion for this gem, and their authors employ its name figuratively and for comparison when they wish to indicate anything white, fine, or perfect. "When you expire I am tempted to think that your soul is jade," (*i. e.*, white,) says the poet *Kao-tchi-ti* in a piece in which he celebrates apple-trees in blossom, a poetical composition which is reproduced in the Encyclopedia *Youen-Kien-loui-han*, and quoted by the author of Yu-kiao-li, or the romance of the two cousins. We may likewise read in the *Fen-loui-tseu-kin*, "The cold penetrates your clothes of jade; you have a skin of jade and bones of jade."

And again, Li-thai-pé, one of the greatest poets of the age of Thung, the seventh century before our era, to give an idea of the skill of some musicians whom he was celebrating, said they had flutes of gold and of jade, as was said by the Greeks, when speaking of an eloquent speaker, "he has a mouth of gold," Chrysostom being so called. "How long does the possession of gold or jade abide with us?" likewise demands the same poet, in his song of regrets. "A hundred years at the farthest," he answers sadly, "the limit of the longest hopes. To live and then to die, behold that is all that is vouchsafed to men. Regret has come, regret has come."

The Memoirs of Chi-i, or Things Neglected or Omitted, comprise some moral sentiments relating to the stone of which we are speaking, as sung by *Tsi-koung* : "Pattern after shining virtue, be like jade, be like gold." The author of the Chinese comedy entitled the Pledge of Love describes nectar as the liquor of jade. "My brother," speaking to his hero Han-fei-king, "speak to me no more of wine, for behold, when you possess the liquor of jade, or any of those fruits which confer immortality on such as taste them, I shall not take it." In another comedy, the Accomplished Waiting-woman, the pretty Fan-sou likewise makes a charming comparison, while walking in a park with her lady friend: "The willows wave their silky verdure, whose pearly streams loosen and fall down like a shower of stars in this limpid pool. They are beads of jade thrown into a crystal basin."

The *Yu-kaio-li* already quoted, a Chinese romance of the middle of the fifteenth century, uses the same comparison to prove that the conceited *Sou-you* resembles a rich man rather than a poet, "covered all over with gold and loaded with jade;" literally encased with gold and enveloped in jade, he seems to say, look at my brilliant raiment. Although preceded and followed by many servants, there was nothing striking about him but his vestments. Finally, in chapter xix of another romance, the Choui-hout-chouen or History of the Banks of the River, a young musician is named Yo-lan, or "the jade chrysanthemum;" and in the Pe-kouei-tchi, or History of the Sceptre of Jade, referring to an infant child named Hong "as that child has such beautiful eyes, the name should be given him of Mei-yu," meaning as handsome as jade, which recalls a passage in the Mirror of the World, "The nature of yu is like the comeliness of a young girl."

By the foregoing it is seen that nearly all the jade worked up in China comes from Khotan. This city is pointed out by the historians of the Central Kingdom by the name of Yu-thian, meaning the jade country, being a part of the ancient Turkistan, now called Alt Hissar or Hexapolis, from the six principal cities observed there. We give here what is found relating to it in one of the numerous *Notices of Khotan*, appended to the history of the Chinese Dynasties. "The source of the Yellow River is in the country of Yu-thian, and it is in the mountains of that country where there is the greatest quantity of yu. There is a river flowing out of it, which, on reaching Yu-thian, separates into two branches, the most eastwardly of which is called the river of White Yu, that flowing to the west is called the river of the Green Yu, and the most westerly of all is named the river of Black Yu. In all three of them this mineral is found, but the colors differ. The river to which the Chinese notice refers is Khotan, or Youroung-khachi. Instead of parting into three branches, it is made up of three separate rivers which have their origin in the Mouslagh Mountains, or mountains of ice, on the north, a region rich in jade;" hence the names of white, green, and black jade, which the rivers bear to the present time.

Another *notice* asserts that the jade of Yu-thian is of five colors, "white, like lard, yellow, like chestnuts cooked in the steam of boiling water, black, like varnish, red, like a cock's comb or painted lips;" but the green and transparent variety, more or less deep colored, is by far the most common. That of a whitish hue partakes of nine shades or gradations of color, from the finest to the commonest. During the years siou-an-no, the *notice* adds, there was at the palace a standard of comparison for all the various tints and shades of jade to which all specimens were subjected when acquired for the emperor, just as now there is a standard for estimating the different degrees of purity in gold, and establishing its value.

This collection of *notices* is not the only work in which are found accounts of different colored jades. The Chi-kung, a book of verses, a collection of odes and songs dating previous to the sixth century before ourera, and arranged by Confucius, speaks of a celestial blue jade; and according to Chi-tchin, who quotes from the Tai-phing-yu-Kian, there is found at Lant-hian a lamb-like jade, which is the color of pastel-blue, whence it appears that the country has received the name of Lan-thian, signifying the pastel country. The author also undertakes to describe the sources as follows: The white yu is found at Kiao-tcheon; the red yu in Fou-yu, a part of Corea; the green yu in the land of I-leon, or Eastern Tartary; the pale-green yu in Tai-tseou; the black yu in the western part of the land of Chou, toward Thibet. The Tcheou-li, when speaking of the coronet of the emperor, says, further, that a band around the upper part is composed of six colors, and twelve pendants complete. All of these pendants are composed of twelve pieces of jade of five colors. Finally the Li-Ki, or book of ceremonies, distinguishes jade as flesh-colored, yellow, white, red, cinnabar, and deep maroon; but, as the yu was a chief ornament of the imperial dress, and as it is to this occasion that the Li-Ki refers, we are led to infer that the word yu comprised other and different kinds of precious stones, since, at the present day, there are not found any specimens which correspond in color to those mentioned in this ancient canonical book.

Now let us return to the jade mine of Kho-tan. The Chinese have resorted to this city for their supplies of the mineral from very ancient times. The *notices*, quoted above, furnish sure proof of the antiquity of these beds. One of them, on the history of the dynasty of Soung, relates, in fact, that the embassadors of the King of Yu-thian sent, in the third year of Kian-te (965,) a tribute consisting of five hundred pieces of jade and five hundred pounds of yellow amber. The city of Yu-thian was moreover annually subjected to this impost levied by the Son of Heaven, as the author of the same *notice* declares that a year was never suffered to pass without the exaction and payment of this tribute.

Finally, in the course of the years Tai-kouan, about 1167–'70, the Chinese desiring to execute some embellishments, a large mass of jade was demanded of the King of Khotan. He sent an embassador with a letter, a copy of which is inserted in the anecdotes relating to Yu-thian, containing the following curious extract: "May the high sovereign of all places over which the sun rises deign to cast his eyes on his five hundred western kingdoms. The He-Han (Lion) lord of five hundred kingdoms, several and combined, addresses himself to the venerable lord of all places within sunrise—deign to look at the four quarters of the universe. I, A-Kieou, prince of four parts of the world, from whom you have demanded a consignment of yu, I have applied myself to the very utmost to comply with your request, but it is very difficult to find pieces which have, as you desire, a tchi and a thsun in length, (=0.335 millimeters.) I have ordered my officers to go upon the banks of the river to search for such a mass, and as soon as it is found I will hasten to offer it to you." It was believed at first, remarks the author of whom we borrow these details, that this reply was merely evasive; but some time afterwards a mass of yu was in fact brought in which measured more than two tchi (0.610 millimeters). Its color was similar to lard, and in all antiquity nothing comparable to it had ever been seen.

The life of Thai-tsou, which forms part of the same collection, moreover, mentions a globular mass of yu weighing 120 kilograms, and Father Cabot declares that he had seen at the Emperor's palace an uncut piece of jade still more curious by reason of its extraordinary weight. "It looked," says he, "as if one man might carry it, but on trial being made it resisted the attempts of four persons to remove it."

The treatise on yu informs me that there are two particular kinds of jade—one from the mountain and the other from the river. That from the mountain is ordinarily veined brown, and has somewhat the appearance of wood; that of the river being veined blue, having more agreeable shades of color and being more wavy. The first is found mostly in China; at Khotan, however, it is from the rivers that the greater part of it is collected. The stream contributing most abundantly has been called the river of jade. We read in the narrative of Ping-kiu-hoci, who went on a mission to the kingdom of Yu-thian (Khotan,) that "the river of jade has its origin in the mountain Kouen-lun. After a course of one hundred and thirty leagues it reaches the frontiers of Yu-thian."

One of the notices of the city of Khotan, written under the dynasty of Thang, in 632 of our era, states that "as soon as they see the locality at night, fully lighted up by the moon, the people plunge into the river to search for the fine pieces." Another notice, anno 938, states that "in the autumn of every year, when the river is at its lowest stage, the King goes out to seek for the mineral. After he is served the common people are permitted to collect it."

It is at Yarkand, near Khotan, that this jade-fishery now goes on, the proceeds being held at such a high value that a monopoly of it remains with the government. The fishery is carried on in the presence of officers, accompanied by a detachment of soldiers. Twenty or thirty divers, forming a line, plunge together into the water, and when one of them discovers a piece of jade he throws it on shore. A drum is then beaten and a red mark is made on a piece of paper. The fishing over, the inspector examines all the pieces and assesses their value. Some masses reach as high as forty centimeters. The city of Yarkand sends every year to Khotan, whence it is dispatched to the court of Pekin, from four to six thousand kilograms of jade. In this amount is not included the cut and sculptured pieces, nowhere more skillfully executed than by the lapidaries of Akson, which is the actual capital of Chinese Tartary, by those of Kashgar, and also by those of Yarkand itself, the former capital, where working in jade engages the most hands.

The variety of jade of which we have been speaking is what is called *yu* by the Chinese, and is designated by Leman as white oriental jade, being white, with a faint greenish or olive shade of color, and of which mineral deposits are known to exist in Japan and India. A very rare sort also is found in China, but not of first-rate value. We now speak of the emerald-green or imperial jade. Of the latter, exquisite specimens were to be seen at the Louirette sale, 1864, but it was almost entirely unknown prior to the French expedition to China. This handsome stone was included in the collection of the Duke de Morny, forming the base of a fire-screen framed or mounted in bronze gilt. It was also seen worked up in spheres, rings, and many forms of jewelry. M. Edouard Fould possesses a large and handsome vase of emerald-green jade, a piece not less remarkable for its size than the quality of the stone, (1869.)

The pretended jades of Europe, America, and Oceania, which are sometimes called the jade of Saussure, and now receive the name of jadeite or nephrite, are only some inferior sorts of compact feldspar under which name Haüy placed them.

Among the latter which usurp the reputation of true jade, we may mention the dull-green jade. It is received from Sumatra, South America, and New Zealand. The natives pretend that they fish it up from their lakes, already fashioned into vases; that it is plastic like clay, becoming on exposure to the air as hard as flint. They make of it vases, hatchets, *casse-têtes*, as well as statuettes. The name of *jade ascien* or *axinien* is derived from them. When it is of a leek-green color, which is really the shade which characterizes orthose-feldspar or Amazon stone, it takes the name of nephritic jade or rather nephrite, because it was for a long time held as a specific in cases of nephritic colic. The latter variety of feldspar is widely diffused in Russia and Greenland. By reason of its imaginary benefits, and the marvelous cures performed by it, this kind of jade obtained celebrity in Europe. Plates of it were cut into fantastic shapes, representing animals, a heart, lozenge, &c. It was then suspended on the person and especially from the neck. Voiture, in one of his letters, addressed to Mademoiselle Paulet, states that, in his time, persons afflicted with gravel had also recourse to these bracelets. "If the stones which you have presented to me cannot break those which trouble me, they will at least enable me to bear the pain with patience; and since it has procured me this happiness, I should never complain of it." He proceeds to say that these stones will scarcely fail to become a scandal to her, for when he opened the letter containing them before one of his friends, he blushed as scarlet as the ribbon on which they were strung, thus compromising the donor. "But having read your letter over, I soon saw that what appeared to be a love token was a remedy, and that the bracelet was not sent to a suitor, but to a sick man." It is not our purpose here to hold up to ridicule the virtue ascribed formerly to gems worn as amulets.

The white jades originating in Europe come from Turkey, Poland, and sometimes Switzerland. It is employed in making the handles for daggers and sabers. If we are to believe Arlak-hel, of Tauriz, author of a small treatise on precious stones, written in common Armenian, of all kinds of jade that which is veined is but little sought after except by the Turks, who prefer it to others.

Millin mentions some hatchets of compact feldspar found in the graves of ancient Gauls; these are of the same nature as the ornaments of jadeite of the stone age exhibited at the Museé de Saint Germain, and of which examples have been discovered by M. l'Abbe Cochet, in the Merovingian tombs of Normandy.

Referring again to the true or oriental jade, we have said that it possesses extreme hardness; in fact, the mineral scratches glass and even quartz. The Chinese and other orientals work it from choice, and with a delight at overcoming difficulties, which would make us doubt its hardness, if against this incredulity we did not set over the traditional patience of the Asiatic workmen. It is unnecessary to employ diamond-powder in these works, since emery-powder is quite equal to cutting it into any required shape. The ancients valued this stone highly, but in the middle ages it does not seem to be referred to, all knowledge of it being probably lost. It would seem never to have been worked more extensively than in our time, since finished articles come to us frequently from India and China. Haüy, the mineralogist, relates that the Indians are skillful in the art of cutting jade, and expresses his wonder at the lightness and delicacy of sculpture which they elaborate from so hard a material, and what may be compared with works executed in alabaster or other less resisting material.

It is declared in the *Notices of Khotan* "that the yu is very hard to cut, and that neither steel nor fire make any impression upon it." The Abbé Grosier, in his remarkable work on China, also affirms that the tenacity of fine sorts of jade is so great that the same processes are used in cutting and polishing it as for agate and precious stones. The harder the stone is to cut the more lustrous will be the polish it receives. As thousands of days do not suffice to finish certain pieces of work, the artists of the emperor follow each other in succession in the palace workshops, and, although operating day and night, still nine and ten years are sometimes consumed on one piece. The expense of executing such works, joined to the original cost of the material, enhances the cost of fine works in jade to an enormous sum. And besides, this stone, so costly, if it be a little thin, will break like glass if let fall to the ground.

Some mineralogists are of the opinion that the Chinese and Indians work the jade into shape before it becomes permanently hard; that is to say, when it is brought fresh from the quarry; and further declare that it is their custom to subject it to a suitable degree of heat after the work is finished, by which it is made still harder. This assertion appears to be very questionable, especially as it is in direct opposition to the authors whom we have quoted, who wrote from what they saw with their own eyes, and constitute now the best authority on the subject. This error appears to have been propagated by a passage in Hoai-nau-tseu, a Chinese historian of the eleventh century before our era, which has been misunderstood or badly interpreted, in which that writer relates that the yu of the mountain of Tchong was heated in a lime-kiln for three days and three nights without any alteration in its color or luster being observed. This does not assert, however, that the Chinese lapidaries submit to the operation of fire all the works which leave their hands. This author only seeks to show, by the trial named, that the yu is unalterable by heat or moisture. Besides, the methods employed in India to cut this refractory mineral is strong evidence in favor of our opinion.

"At the Exposition of 1854," (London,) says Baron Charles Dupin, when reporting on this exhibition, "the perfection of the work as well as the designs, which the stones cut at Lahore presented, were highly admired." They were executed by a method of which we give a description, obtained from Mr. Summer, resident at Cambay. The rough gem is fixed upon the steel axis of a lathe and cut away until its form approaches that of a sphere; it is then polished by means of a composition of gum lac and corundum. (Granular corundum is the next hardest mineral after the diamond; emery, which the ancients called *smyrris*, from the Hebrew word *smir*, being a variety of it. It is found in Bengal, Ceylon, and especially in China, where its use as an abrading material dates back to the earliest times. It is the mineral used in polishing the diamond.) Cups or vases or other art objects are worked out according to fixed designs by means of the lathe. The first polish is obtained by friction with common polishing-stones. The concave part is fashioned by the help of a pointed tool armed with a diamond, which perforates to the depth of 6 millimeters over the whole surface, so as to present the appearance of a honeycombed structure. These innumerable circular holes are afterward broken into one and the surface leveled. This process is repeated for the purpose of deepening the cavity, 6 millimeters at a time, until the desired shape of the interior of the cup is gained. The final polish is given by a revolving mold, which fits the interior cavity, these molds having the same composition as the polishing plates commonly used with a lathe. At the Exposition of 1851, we beheld fine antique cups of crystal, of jade, and of agate sent from Lahore. The surfaces of some were plain, without any ornament. We can imagine that these cups, of making which the exact process is unknown, have been cut and polished after the method we have described as practiced at Cambay. Other cups and vases from Lahore were engraved with skill, and some of them were encrusted with precious stones.

Let us devote a few sentences to the numerous objects of art and *vertu* executed in jade by the Chinese from the earliest times. If we open the Chi-King, it will be seen that the princes and high mandarins, before the sixth century of our era, wore rich girdles, to the ends of which were attached precious stones. In ancient times, when a man of distinction wished to receive his friends in an honorable manner, his first care was to provide them with pendants of precious stones to decorate their girdles. Thus a wife says to her husband, "Offer precious stones to thy friends when they come. They will wear them hanging from their girdle. Salute thy friends by offering presents to them." The prince Tcheou Koung, author of the Tchou-li, or the Fixed Etiquette of Tcheou, says, likewise, in his sixth book, that the officer who presided over the jade-magazine was charged with preserving the jades belonging to the imperial vestments; and the jades of the imperial girdle refers, according to a commentator, to twelve bits of jade which decorate the imperial cap, and also, according to Licou-yng, the plume of the bonnet, and other precious stones. The jade of the girdle, after another commentator, indicates a piece of white jade attached to a silk girdle worn by the emperor.

These jewels, it seems to be certain, were no other than jades or yu. Ouang-po, a poet of the seventh century of our era, speaks of them in these terms: "At the girdle of the king were dancing beautiful gems of jade." At this time also the color, form, and dimensions of these gems varied according to the rank of the person who wore them.

La-thai-pe, a poet of the eighth century, informs us how the workmen of his time were skilled in making every description of jewels in jade. We can judge by the following verses, which he puts in the mouth of a wife: "These swallows of jade, the ornaments of my hair, were worn on my head on the day of our marriage. I offer them to you now as a souvenir. Do not fail to wipe them softly with your silken sleeve."

The most ancient objects of art executed in jade are perhaps the instruments of music called king's or sonorous stones, guitars, and different forms of flute. They have even cut the jade into bells. "We have seen," says P. Amyot, "in the palace of the reigning emperor a guitar of nearly three feet and of a fine green tint." According to Tcheou-li, these musical stones were much in use during the dynasty of Tcheou, which was twelve centuries before our era. We may consult in this respect the above-named treatise of P. Amyot, the plates of which represent many very ancient musical stones, sculptured in perfection, and bearing rings cut out of the same chief mass.

The Chinese comedy, entitled "The Accomplished Soubrette," informs us that the sonorous stones serve likewise as a hydraulic clock. "Observe that the drop of water falls on the clepsydra of sonorous jade," as Fanson says to Pe-min-tchong.

In the first chapter of Choui-hou-tchouen, or History of the Banks of the River, a comic romance exceedingly relished in China, a description is given of a feast given by Siao-wang, governor of the imperial palace, to the Prince Touan. That description is, in many respects, very curious, and shows to what extent objects of art sculptured in jade were sought for in the twelfth century of our era. At the second course it is related "that the Prince Touan, rising from the table by chance, passed into the library, where he saw, on the bureau of the governor, a paper-weight, representing two small jade lions, most admirably sculptured. As works of art, in fact, these works were perfect both in the polish and design. The Prince Touan, who had taken up these two small lions to examine them with care, and could not relinquish them, holding them in his hands, he fell into an ecstasy whilst contemplating them, and exclaimed without ceasing, "It is a master-piece; most wonderful." "I have, besides, a crayon-holder," says the governor, having noticed that the prince took such pleasure in looking at his paper-weights, "it is in jade, and represents a dragon, and the same artist sculptured it." If we are to credit Father Mailla, all these details are of high historic fidelity. Tchao-ki, Prince of Touan, who became emperor under the title of Hoei-tsong, is represented as a prince naturally curious and a lover of rare works well executed. A trifle of this kind held his attention for whole days. The courtiers, who had observed this weakness in their monarch, searched through the country for the most interesting paintings, the most curious cut stones, and the rarest mechanical works, to offer them to the emperor.

It is principally in the execution of vases of jade that the skill of Chinese artists shines forth. The quantity of them to be met with is immense, from flasks, in which they keep snuff, to drinking-cups and incense-burners, all showing to what perfection the art of cutting, sculpturing, and polishing hard stones in China has attained.

Among the drinking-cups we would mention principally the kia, vases made of precious stone for containing wine. A cup of this kind of the period of Tcheou, 1122 B. C., was made known to the world, during the last century, by the Emperor Khien-loung, and is described in his "Ancient China," by M. G. Pauthier. The poet Tsiu-tsan seems to allude to this class of cups when he says, in his "Improvisation before the Flowers," "the perfume of these poor flowers penetrates into the cups of jade and is embalmed in the wine of autumn."

With those may also be ranked the vessels or dishes for service at festivals, and which are shaped so as to receive the meats. There is mention made of these vessels in "The Two Educated Girls," where the author of this pretty romance gives a description of an imperial banquet: "At the end of some instants the music of the dragon and the phœnix is heard, and at once is served in vases of jade the most refined meats."

Some of these vessels are of very large dimensions. A poem of Pei-y-tchi, entitled "The Measures of Jade," makes mention of two vases, broken by Fan-tseng, each of which would contain a teou, that is to say, large enough to contain one million two hundred thousand grains of millet, which is a capacity certainly very uncommon. Pei-y-tchi thus expresses his indignation: "In his time no good counsel was listened to; what apology did Fan-tseng make for these great vessels of jade? . . . . His brilliant polished blade leaped from its scabbard pure as water, brilliant as an icicle, and the transparent pieces of the precious stone flew round like flashes of light."

To conclude our statements as to the rare skill of the orientals in the difficult art of working in jade, we quote a passage from the *Notices of Khotan:* "In the first year Kian-tchong of the reign of Te-tsoung, (780,) one of the officers of the palace, named Tchou-jou-yu, was sent into the country of Yu-thian to seek for the stone yu. He succeeded in obtaining a tablet, five clasps, a magnetic ear-ornament, three hundred small pieces for girdles, forty hair-pins or skewers, thirty boxes, ten bracelets, three rods, and a hundred pounds of uncut masses." He loaded this precious freight on camels and returned; but, being deceived by false information, he took the wrong road, and was plundered by Hoei-he. A little while afterward all the abovementioned objects came on the market.

Of all the works of art, the most interesting, beyond all question, are the jade figures affixed to the magnetic chariots, which were invented, according to the historians of the Chinese Empire, by the Emperor Hoang-ti, 2637 years before our era. A valuable work on Chinese antiquities, in twenty-four volumes, entitled Poh-kou-thon, or illustrated descriptions of antiquities, preserved in the private collections of Chinese amateurs, contains, in the part Kou-yu-thou, which is entirely occupied with works in jade, some fifty objects, among which we may distinguish the figure of a personage which the Chinese editors refer back to the dynasty of Chang, from 1783 to 1134 before Christ. The figure represents the man of the magnetic chariot elevated in the front of the car, pointing with extended finger to the south (Tchi-nan-kiu) and sculptured out of yu or jade. The man, turning on a pivot, extends his right hand in the direction of the south, or that point of the compass opposite to the north magnetic pole. It is important to have concealed in the figure a strong magnet, which always points to the north, and the man's arm is thus directed to the south, which is the sacred aspect of the heavens among the Chinese.

To comprehend the patience and the incredible resources of oriental workmen, one has but to cast his eyes upon certain antique pieces in the Morny collection, as described by M. Albert Jacquemart. For example, a jade has been fashioned into an open chalice, surmounted by a squatting Buddhist figure, or Hindoo. The cup is supported by three eagles with extended wings, each one holding in its beak the figure of a lamb *cut out of the same mass;* their talons rest upon scroll ornaments which re-enter the base, and, terminating by three balls, serve as a stand for the whole. The whole work stands out so distinctly and the undercutting is so deep, that one fears to see it fall to pieces at the slightest touch. Two small vases, one of them without mounting of any sort and the other hanging in its Kia-tse of carved wood, appear more wonderful still; besides the body of each vase and its lid, there is worked out from the same mass of jade two movable rings, attached below to the handles of the vases, and above to a cross-piece in shape of a yoke, on which is clasped a gilded or enameled bat, which forms the point of suspension.

If we contemplate the mechanical difficulties of every kind which attend the working in this hard and tough stone, to be honey-combed with the diamond-pointed drill and polished with emery, we may begin to appreciate the merit of such complex works and the time which is expended on them, for, as we have already observed, almost the entire life of a man is required to reach a good result by the laborious and patient Chinese.

The Tchou-li, or etiquette regulations of Tcheou, twelfth century B. C., preserves for us some ancient usages relative to jade. Thus the great administrator-general, Ta-tsai, serves as an assistant to the emperor in some details of official receptions, as "the homage of jade and precious stuffs, the offerings of jade presented, the jade throne, and the jade vase." The orientalist, Edouard Biot, to whom we owe the first translation of this important code, adds the following comment: "The rare productions which princes bring from their kingdoms as offerings to the sovereign are placed in jade vessels. The seat or throne of jade supports the emperor as he sits on the hassock or cushion. When he rises, the seat of jade is set forth as a mark of honor, and those who have come to pay their homage are invited to drink from the vase of jade. In the case of funerals, the same officer attends to receive presents in jade made to the defunct prince and the piece prepared to be placed in his mouth."

The treasurer, Ta-fou, has special functions to assess the value of the first-class objects of gold and jade. Next to him is the officer placed over the magazine of jade, (infou,) and charged with keeping gold, jade, and all other precious articles which are the property of the emperor. The yu-jin, those who work on jade on the palace, are also under his direction.

A few words now upon artificial jades. According to the words of Telfaschi in his "Kitab-al-Ahdjar," or "The Book of Flowery Thoughts on Precious Stones," a Persian treatise in Arabic, the "yeschm," (Persian name for jade,) which is found in commerce, is of two sorts, one being truly a mineral, and the other produced by art. The mineral jade is yellowish, of the aspect of old ivory. It is hard and shining, and is a natural product. But the impossibility of distinguishing the real from the artificial jade causes them to be held at the same price. It is supposed that all the vases found in commerce are of the natural yeschm, which gives them their exorbitant value.

According to this passage we might infer that artificial jade was not to be found in Persia. But it is found in China. The fourteenth book of Tcheou-li expresses indignation at the counterfeits and commercial frauds already well known, twelve hundred years before our era, a testimony fully confirmed by the chapter of imperial regulations (Wang-tchi) in the Ti-Ki or code of ceremonies.

Teng-you en-yang also, a commentator on the ritual of Tcheou, who flourished in the time of Ming, declares that adulterations abound in everything. The common dealers dampen the rice and mix hemp with silk, the pedlers make jade out of common stones, the shopkeepers imitate antique objects with modern materials and sell the new for the old.

The Arabian writer, Mahommed ibn Mansour, author of the "Djeouar-Nameh," or The Book of Precious Stones, declares that in China false jades (yescheb) are manufactured, but can be distinguished from the natural stone by a slight smoky odor. "If a vase of the true yescheb is broken it may be repaired with counterfeit material which can with difficulty be distinguished from the real, and Telfaschi declares likewise that artificial jade is made in China by the combination of many substances. Vases so made are imported into Arabia. I have not seen any such in Egypt or Syria." He expresses himself with complaisance relative to some successful attempts he has himself made for this purpose in the country of the Pharaohs. It is understood that this artificial jade is a kind of glass known as *rice paste*. In China and Japan they manufacture this as a very hard enamel, but at the same time quite fusible, of which there is a chemical analysis by Klaproth.

These statements are sufficient, as we think, to place amateurs on their guard against counterfeits, which in both the East and the West are being more and more practised in all departments of curious and antique works.

Among Chinese monuments of art of the first rank which exist in Europe, we must first notice the admirable works in jade belonging to the crown of France kept at the Garde Meuble. An inventory prepared in 1791 mentions a grand oval cup, or vase, in greenish jade, of the estimated value of 72,000 francs; also a round cup in white jade of 12,000 francs. Unless we are deceived, these cups are now exhibited in one of the rich glazed cases of the Gallery of Apollo, Museum of the Louvre, Nos. 630 and 637.

The great Paris Library, in its cabinet of antiquities, possesses also a skiff or gondola in green jade, presented in 1114 to the monastery of St. Denis by Suger, who bought it for 60 marcs of silver from the money-lenders with whom Louis VI had pledged it ten years before.

We must also mention the fine jades of the British Museum in London, those of the Chinese Museum of the Louvre and of Fontainebleau, of the Museum of the Hague, of the Japanese palace at Dresden, and the superb pieces, cut and uncut, in the Museum of Mineralogy at the *Jardin des Plantes* and the *Ecole des Mines*, in Paris. Among the private collections, that of M. Montegay, formerly attached to the Chinese mission, those of MM. Negroni, Pourtales, and especially of Duc de Morny, lately dispersed, included rare objects of this nature; and extremely curious specimens may also be seen in the cabinets of MM. Count Choiserd, Count Blou, Marquis Hervey Saint Denys, Admiral Page, Viscount Ch. de Montauban, and others.

The amateur last cited possesses a cup dating from Nien-hao, 1736–'95, and showing this inscription: "Fang-kou, similar to the antique." It is very difficult to distinguish copies from originals, as M. Albert Jacquemart says on this subject, when treating of sculptured works in an unchangeable mineral, preserved by privileged classes, often devoted to religious uses and reproduced in the same invariable design. The Emperor Kien-loung, the restorer of the ancient splendors of China, has contributed not a little to this end, and increased the difficulty, as he was pleased, according to written testimony, to have accurate copies made of old types of work, and to express all inscriptions in the characters known as ta-tchouan.

The art of sculpturing in jade, as to its origin, is referred back to the most remote ages in the East, especially in China. Archæologists enlarge upon these antiquities of the Celestial Empire, upon the infinite delicacy of the work, as due to the patient assiduity of a man who is never interrupted, and in whose estimation time is of no value. An example is found in a narrative of a voyage made by the Arabians in the ninth century. "The Chinese," says the Arab author, "are of the number of God's creatures having the greatest manual skill in all that relates to design, the art of working, and every species of handicraft, not being surpassed in this respect by any nation. In China a man will execute by manual dexterity that which no person could believe to be possible." But unfortunately this industry instead of now advancing is everywhere on the decline. Many important secrets of the skilled workman are lost, and at this date the most skillful are unable to attain to the perfection and finish so much admired in works of antiquity, so that the desire on the part of rich Chinese to procure ka-toun or real antiquities is much restricted.

As to the true principle of esthetics, several authors, Ghirardini at their head, have concluded that with the Chinese the plastic arts and rules of absolute beauty are uncomprehended. The English embassador, Staunton, confirms this view by declaring that the Chinese copy natural objects in a servile manner and do not possess any sense of the beautiful. These severe criticisms might appear exaggerated if in his Asiatic miscellanies M. Abel Remusat had not pronounced the same judgment. According to him, in fact, the sculpture which the Chinese bestow on objects of small dimension is only conspicuous for an extreme finish, and fails entirely in the direction of elegance or correctness of form. He adds: "They are faithful and minute copyists, but their taste is often fantastic, vicious, and far-fetched."

ANTIQUITIES IN GUATEMALA.

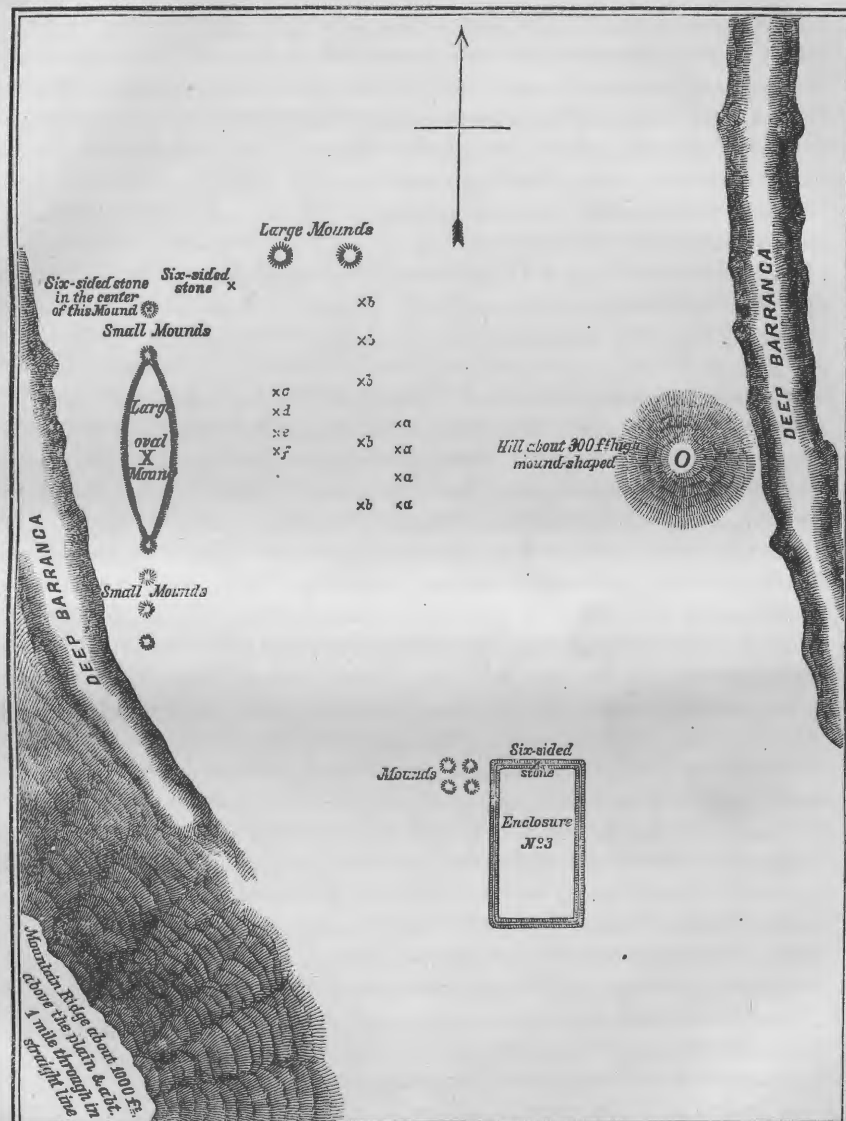
By Hon. Geo. Williamson,
United States Minister to Central America.

The locality examined, which I took to be the remains of a place of worship, was in the coffee-plantation of the hacienda of Don Pedro Aycinena, near the city of Guatemala, and has been cultivated for nearly fifty years. It is a quadrilateral of four unequal sides, which appears to have been inclosed by an earthen wall or embankment about 10 or 12 feet high. The longer sides run from north to south and are 150 feet in length; the shorter sides run from east to west and are 90 feet long. On the west side, in a direct line with the shorter sides, are four small mounds probably 20 feet high. The one nearest the northwest corner is the one I caused to be opened. In the north end of what I shall designate for convenience No. 1, was found, many years ago, a piece of wrought stone somewhat in the shape of a crocodile's head. It is now in the possession of the owner of the hacienda of Naranjo, Don Pedro de Aycinena.

After deciding that the embankments had not been a Spanish or Indian fortification, and after taking the advice of my companion, the Duke de Licignano, I decided to open the mound nearest the northwest corner. It was cut down to the level of the surrounding ground by cross ditches from north to south and east to west. Nothing was found but the head of a small stone idol, the edge part of a greenish stone hatchet, and a great quantity of broken pieces of obsidian and pottery. It was impossible to reconstruct any vessel of the pottery, but judging from the thickness of many of the pieces and from the large size of solid cylindrical parts that appeared to have been handles, it occurred to me this pottery might have been burial vessels like those sent to the Institution from Nicaragua last year by Dr. C. H. Berendt.

The earth which composed the mounds and embankment seemed to be like that of the surrounding surface, but after carefully searching around within a considerable radius from the center of No. 1, I could not discern any place from which the earth appeared to have been excavated.

The next place I examined, No. 2, is in the same field, and exactly in



ANTIQUITIES IN GUATEMALA.

NOTE.—Nos. 1 and 2 referred to in the description are on the west side of the high mountain ridge.

shape like the first described. The mounds of No. 2 are on the east instead of the west side and are much smaller. The size of No. 2 is 120 feet by 60 feet.

The results of No. 1 were too unsatisfactory to induce me to make any excavation of No. 2. In the mean time I had examined No. 3, about three miles distant from No. 1, and on the other side of a high mountain ridge, which at that place runs tongue-shaped into the plain of Guatemala.

No. 3 was larger than either of the others, and has the mounds now much reduced in height by continual cultivation and washing on the west side. These are all the rectilinear works or embankments that I have found or been able to hear of in the plains of Guatemala. No. 3, however, is peculiar in this, that it commands a view of a small plain, partly inclosed by nature and art, which has some mounds and stones in it that are certainly singular if not interesting. This plain, partly inclosed as stated, is in the form of a parallelogram, with its long sides running north and south or nearly so.* It contains some curious stones placed, evidently by design, in north and south lines, or nearly so, and most if not all of them roughly wrought. I had been anxious to see this, but had been deterred because I had heard it was almost inaccessible. One of the stones is a corner post in a street of the city, and two others I had seen and examined in the yard and cattle lot of the hacienda of Naranjo. Upon inquiring where they had been brought from, I was told that the spot was about three miles in a straight line from Guatemala, but impossible to reach on horseback from the city, as impassable "barrancas" or cañons intervened. It was noticed the stones seen had all been wrought into six-sided posts or columns and were of a dark-colored species of granite.

In the partly inclosed plain there are three rows of stones still standing in the ground. On the east a large isolated hill rises from the plain to a height of probably 300 feet, which is so much the shape of an artificial mound that its size and an examination of its surface only prevent me from believing it is the work of man's hands.

On the north side are several large mounds. On the west is an unusually large oblong-shaped mound facing the hill or mountain on the east and opposite to it. The distance of the bases apart is about 600 yards.

On the right and left of this oblong-shaped mound is a continuation of smaller mounds, two of them apparently connected with it, and the others disconnected. This range of mounds extends a distance of several hundred yards, so as to form, as I think, the west side of the inclosure.

On the east side is higher natural ground than the plain, and on the southeast side, with its shorter side toward the plain, is the rectilinear

* The variation from a due north and south line, according to my compass, was about 5° to the west, and this variation seems to be uniform in all the mounds and lines of stones herein mentioned.

figure with high earthen embankments, which I have designated as No. 3.

In the rear of the hill, in the plain of Guatemala, is a very deep barranca, and in the rear of the oblong mound is also a very deep barranca, which separates the plain from the mountain ridge.

But to return to the stones. The line on the outline sketch marked thus, *a*, *a*, *a*, *a*, represents the six-sided stones. They are about 8 inches in diameter and appear to be set deeply in the ground. But four of them are now left standing. They are about 40 feet apart and are on the side next to the hill O. On the next line, 60 feet toward the west, are five very large stones, rudely worked, if worked at all, of quite a large size, and standing above the surface about an average of 5 feet. They are marked on the sketch *b*, *b*, *b*, *b*, *b*. These are about 100 feet apart. About 125 yards from this line of stones *b*, *b*, *b*, *b*, *b*, are four wrought stones. They are directly in front of the central mound on the west of the plain, which I have marked X in the sketch. The line is nearly parallel to the others spoken of. It is marked *c*, *d*, *e*, *f*. This line is probably not more than 60 feet long. The stone on the north end of the line *c* is small and not more than 18 inches above the surface. The next (*d*) is larger and about 2½ feet above the surface. The next (*e*) is very large, and stands about 5½ or 6 feet above the surface. It must weigh several tons. I think it is about 1 foot thick, 4 feet wide, and probably 10 feet long. It does not stand perpendicularly, but is slightly inclined toward the east. The next stone in this line is *f*. It is also very large; quite as large as stone *e*. It has a hole cut about the center of it, nearly 3 feet from the surface of the earth. This hole is just large enough to admit the insertion of a small man's shoulders and the passage of the head. That part of the hole toward the east is cut so that the face has to be horizontal when the head is passed through, and there is a notch or cut in it, so that if the head were once passed through; the insertion of a piece of wood or stone in the notch would render it impossible to move or withdraw the head.

On the same side (east side) there is a working which, if the stone was so used, would make the blood flowing from the neck of a person whose head was passed through the stone, and was beheaded in that attitude, distribute itself nearly all over the lower part of it. I thought this place might have been used for the purpose of human sacrifices, (at one time common in Central America,) and for what were called religious services. It seemed probable that an excavation of the oblong mound X, directly in the rear of these, would yield something interesting. I regret to say this expectation was not realized. It was cut through from east to west, but nothing was found except broken pieces of obsidian and crockery.

The plain of the stones is called by the Indians, "The palace of Montezuma." They say it has been there "always," but that many of the six-sided stones have been dug up and carried away.

So far as I can learn, the English minister who accompanied me on my first visit to the place, and myself, are the first foreigners who have visited the spot. This ruin is not mentioned in any work on Central America that I have ever had access to; but there is a tradition that a large Indian population lived around the base of the high mountain ridge shown in the sketch.

COLLECTIONS OF HISTORICAL DOCUMENTS IN GUATEMALA.

BY DR. C. H. BERENDT.

The city of Guatemala having been for nearly three centuries the seat of the colonial government of the "Kingdom of Guatemala," (comprising parts of actual Mexico and the other Central American republics,) a vast amount of documents has been accumulated and carefully preserved by the various departments of administration, by the municipalities, and in the convents and churches. After the separation from the mother country, and with the suppression of the monastic orders, they have become the property of the government and of the public libraries. Their extent and importance are but imperfectly known, but, to judge from what scientific travelers occasionally report, from what we glean from the works of the few native scholars which have reached the scientific world abroad, and from what I have seen myself during a month's sojourn in the capital, it is safe to say that they contain many rare and unique documents whose study would considerably extend our knowledge of the history of this continent, particularly regarding the periods of the conquest and of the Spanish dominion, and also of the condition of the country and people before the conquest. I heartily concur with Mr. Williamson in the wish that these treasures, by carefully-made copies, might be made accessible to other students besides those who happen to visit this country. There is a particular reason for wishing that such may be done soon, as else it might be too late. The actual government of Guatemala, wide awake as it seems to be to the material progress of the country, is strangely neglectful with regard to the preservation and utilization of those scientific treasures. At the simple request of a foreigner, a German residing in Nicaragua, a considerable amount of most valuable original documents have lately been given away, with astonishing coolness, as so much waste paper, to the Nicaraguan government, which never asked for them nor will care to preserve them. It is to be feared that invaluable sources of information may thus be lost forever if not saved from perdition by transcripts made in time.

The MSS. to be found here are scattered through a number of archives and public and private libraries. Of important works one volume belongs to one individual, another is found at another place; of some only parts or fragments are remaining. The principal collections are—

1. The National Archives, containing the archives of the colonial administration, carefully arranged and kept for many years by Don Juan Gavarrete, but now in incompetent hands. It is this collection from which some fifty fascicles relating to Nicaragua, (they comprise original reports from the local authorities, from residing judges and visiting functionaries, from bishops, curates, and missionaries, &c., covering, in uninterrupted succession, the period from 1560 to 1821, more than 1,200 documents in all,) have been given away, and are now rotting in their boxes at Managua, where the dampness and the destructive insects which abound at that place must soon destroy them. No catalogue exists of the remainder.

2. The Archives of the "Audiencia" (the high court of justice during the Spanish reign) in the palace of justice. They are in the greatest confusion, and, in the opinion of those who have had access to them, have never been revised.

3. The Archives of the Municipality. They contain the municipal records from the oldest times, besides a few valuable manuscripts, among them the original of Bernal Diaz's "Historia Verdadera," the author (whose existence Judge Wilson holds to be a myth) having been a member of the municipal council of the city of Guatemala.

4. The Library of the University. A catalogue by Don Antonio Batres exists in print, which, though a poor work, full of blunders and inaccuracies, gives at least some idea of the rich contents of that vast hall. I hope a copy has been sent to the Institution, as promised to me by the author.

5. The Library of the "Sociedad Económica." A catalogue of the "ethnological sections" (comprising also the historical works) by Don Juan Gavarrete, is printed in the last February and March numbers of the paper published by the society, and separately in a quarto pamphlet. Both have been sent to the Institution, if I am correctly informed.

Works which I would recommend to have copied first are those by Jimenez, of which, as far as I remember, no transcripts exist outside of the city of Guatemala. The "*Recordacion Florida*," by Muñez y Guzman, of which one volume in manuscript copy is in the Lenox Library; the anonymous "Historia de la Provincia de San Vicente Ferrer de Chiapa y Guatemala," comprising the "Isagoge apologético," so often quoted by Pelaez; Bernal Diaz's "Historia Verdadera," (the printed editions being considered defective both in correctness and completeness—a copy is actually being made for the Mexican government;) the writings of many ecclesiastical authors, such as Cano, Molina, Montoya, Cortés y Lara, Goicoechea, &c.; the records or memoirs written by Indian authors in Indian languages, among them the manuscripts quoted by Brasseur under the name "Memorial de Tecpan-Atitlan, &c.

With regard to the permission to be obtained from the government and special managers of the mentioned collections for searching and copying manuscripts in those archives and libraries, I have no doubt it would be willingly granted. The person recommended by Mr. Williamson for making the transcripts (Don Francisco Gavarrete) is fully competent for the task as to the works written in the Spanish language. A translation into English seems not advisable. Whoever wants to study the history, ethnology, linguistics, &c., of Spanish-American countries, must, from necessity, understand the Spanish language, and if he does not, he ought to begin by learning it. The work of copying the writings in Indian languages requires a scholar conversant with them and accustomed to decipher the often illegible old manuscripts, or the copies would be worthless. The same may be said with regard to the arduous task of selecting from the unknown contents of those archives such as would be worthy of the trouble and expense of copying; it would require a person familiar with the literature of this specialty, particularly the various Spanish, Mexican, and other printed collections of historical documents, to avoid copying writings which already exist in print.

Regarding excavations to be made in the neighborhood of the city of Guatemala, I have no opinion to give as to the probability of their success. In the wide valley-plain around the city, and particularly to the west, at the foot of the mountains of Mixco are many small mounds, some of them grouped together, forming lines here, squares there; and antiquities (principally clay and stone implements) are occasionally found. Some of these mounds may be of a sepulchral character, and in that case they may contain interesting objects of antiquity. There is certainly a great deal of work still to be done in American archæology, and no part of the continent has so great an interest for the student as the region inhabited by the nations of the Maya-Quiché family, for bearing testimony of the highest pre-Columbian civilization of this continent. The distinguishing features of antiquities belonging to this group are far from being satisfactorily established, and any additions to our knowledge in this regard would be highly acceptable. But the difficulties in reaching results from partial researches upon a ground which has been inhabited successively by tribes of various nationalities and different degrees of civilization, and, on the other hand, the tendency of the day, by which the prehistoric man of the old world absorbs all the interest and attention of students, even in institutions which are expressly dedicated to American archæology, are great obstacles in our way, and convince us that the time has not yet come—as certainly it will and must come—for a co-operative and successful working of this branch of American science. If, however, the Smithsonian or any other museum or academy were willing to defray the expenses of digging for antiquities, I think there might be named hundreds of other places in Central America more likely to give returns than the neighborhood of the city of Guatemala. Mr. Osbert Salvin, the ornithologist, dug up one or two of those Mixco mounds not more than a year ago, but, as I am informed, he found nothing therein of antiquarian interest.

OBSERVATIONS ON THE PRE-HISTORIC MOUNDS OF GRANT COUNTY, WISCONSIN.*

By Moses Strong M. E., *Assistant State Geologist.*

During the course of my geological examination of the lead region of Wisconsin in the summer and fall of 1874, my attention was directed to the numerous and remarkable tumuli which are found in the valleys of the Mississippi and Wisconsin Rivers, and on the adjacent bluffs.

The entire number of mounds, of which this article treats, may be classified in three kinds, according to their form.

1st. *The round mounds.*—They are perfectly round or circular at the base, and are dome-shaped or conical, according to their height, which varies from 3 to 15 feet. By far the larger number—probably as many as four-fifths—are less than 5 feet high, and are spherical segments, with an average diameter at the base of about 25 feet. The conical mounds usually exceed this diameter and height, and are always rounded off at the apex; whether this was by design, or is a modification due to the lapse of time, it is difficult now to decide. Some of the largest attained a diameter of 50 feet and a height of 15 feet. Again, many of the round mounds were so low as almost to escape observation, and sloped so gradually into the ground on which they were thrown up that the true diameter could not be exactly ascertained. No traces were seen of ridges or trenches surrounding any of the round mounds, such as are described in other localities, as at Hutsonville, Ills.; nor were there any terraces on their sides, or any appearance of a platform on their summits. All the circular mounds were perfectly plain and simple in their structure.

2d. *Oblong mounds.*—These tumuli are invariably straight and of various lengths, from 50 to 300 feet. They are seldom more than 4 feet in height, and will average about 2½ feet high and 15 in width. They always slope gradually at the ends to the ground. Sometimes these mounds are found in a long straight line, and, at others, in parallel rows; but a systematic arrangement is always apparent. Excepting in their length, there is less variation from a uniform standard seen in the oblong mounds than in any other kind.

3d. *Effigy mounds, or those having animal forms.*—These are the most singular and interesting of all; perhaps for the reason that it is most difficult to find any theory which rationally accounts for their existence. They are found of all dimensions as regards length; being from 50 to 200 feet long, and are usually a little higher and wider than the long mounds. Their average height is about 4 feet, and their width 25. They usually represent animals lying upon one side, with the head up, and legs apart, as if in motion. Representations of the human form were not observed, although such exist north of the Wisconsin River.

* Extract from the report of the Wisconsin Geological Survey of 1873–'74.

Three instances of the representation of birds were observed, and one of an animal like a lizard.

That these mounds were intended to represent animals can be seen at a glance, but what particular genus of animal is seldom so evident. In general, all that is plainly seen are the head, neck, body, and legs of an animal. Sometimes there are added to them, ears, horns, or a tail, the two latter being quite infrequent.

Localities of the mounds.—The following description of the several localities where mounds were seen, with a few explanatory remarks, will convey an idea of the former works of the mound-builders, and the sites selected by them for their tumuli.

1. S. E. ¼ of N. E. ¼ of sec. 36, T. 4, R. 2 E.—Five straight mounds, each about 50 feet long, situated in a direct line coinciding with the axis of a low ridge on which they are built. This ridge is the terminus of a long divide between two branches of the Pecatonica River. The mounds are about 200 feet from the eastern branch and about 30 feet above it. As a dwelling-site it would have been very convenient.

2. S. W. ¼ of sec. 25 and N. E. ¼ of sec. 26, T. 4, R. 2 E.—Proceeding in a northwesterly direction from the preceding locality, and following the crest of the same dividing ridge, numerous long mounds are seen lying parallel to the axis of the ridge. This land is now under cultivation, and the mounds are nearly obliterated.

3. N. W. ¼ of sec 22, T. 7, R. 4 W.—On the summit of a bluff at the junction of the Green and Wisconsin Rivers a straight mound was observed; it is 200 feet long, 2 feet high, and 6 feet wide. From this point a beautiful view of the valley is obtained. No other mounds of any kind were found near it.

4. N. W. ¼ of sec. 25, T. 7, R. 5 W.—At the mouth of Dry Hollow and near the bank of a bayou of the Wisconsin River, are a number of mounds, both long and round, scattered about without any apparent order of arrangement.

5. S. W. ¼ of sec. 26, T. 7, R. 5 W.—Proceeding down the valley of the Wisconsin to a deserted farm known as the "Schlundt place," several long mounds were seen on the road, lying parallel to the foot of the bluff, and a few yards from it. At the Schlundt house, one long and three round mounds were seen, one of which is quite conspicuous for its size. It has the form of the frustum of a cone; the diameter of the base is 40 feet, the diameter of the upper surface 28 feet, and the height 4 feet. In the center of this mound a cottonwood tree 17 inches in diameter is growing. The appearance of the mound indicates that it has been cut or worn down several feet, to make its upper surface level; and that the tree was subsequently planted, perhaps for shade. The mound is constructed of sandy clay, which, however, contains much less sand than the adjacent ground. The material of which the mound is constructed may have been brought from the bluff, which is not far distant. About 100 feet south of this large mound, is a small circular

mound, 15 feet in diameter, and 3 feet high. Thirty feet east of the small mound is a straight one 77 feet long. Following the road for about a quarter of a mile west of the "Schlundt place," a mound was discovered which is shown in Fig. 1. It is situated immediately on the bank of the Wisconsin River, and about 50 feet from the foot of the bluff. This mound is the only one of its kind seen. It is perhaps intended to represent a bird with its wings and tail spread, as shown by the circular expansion at the rear end. If this is its design, it is not nearly so well proportioned as the other bird mounds which were seen, none of which, however, had their tails spread.

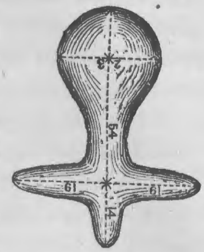


Fig. 1.

6. N. E. ¼ of sec. 2, T. 6, R. 5 W.—Making a short detour from the valley of the Wisconsin, up the valley of a small stream on which the village of Millville is situated, we find the singular mound shown in Figure 2. It is situated in a meadow owned by Mr. Kidd, the miller, and about 300 feet south of his house. The mound lies on the level ground, with its limbs pointing to the creek, which is distant but a few yards. The meadow has been under cultivation for a number of years, so that the mound is much reduced in height, although it can still be distinctly traced. The remains of several others were observed, but they are so obliterated by cultivation that their forms can no longer be identified. As it lies upon the ground the effigy is not particularly suggestive of any known living animal. The fore limbs are the longest, and each longer than the body, while the neck has been omitted in the construction of the animal. Altogether, it is one of the most singular effigies seen, and the only one of its kind.

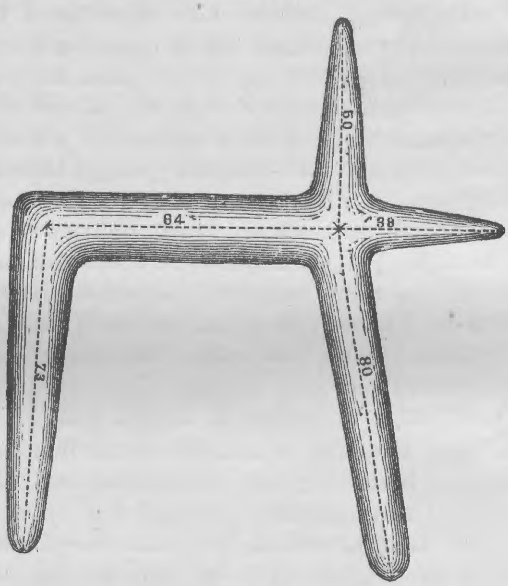


Fig. 2.

7. Center of sec. 15, T. 7, R. 5 W.—This locality was formerly known as Warner's Steam Mill, and is situated on the bank of the Wisconsin River. Here is a strip of bottom land half a mile wide, lying between the bluffs and the river, on which a large number of small circular and conical mounds were found scattered about without any apparent law of distribution. No straight or effigy mounds were seen.

8. ¼ post secs. 5 and 8, T. 6, R. 5 W.—On the new road from Millville

to Bridgeport three straight mounds were found, from 100 to 150 feet long. The mounds lie at the foot of the bluff, and parallel to it, about 15 feet above high-water mark, with a bayou of the Wisconsin in front of them and but a few yards distant. Nothing particular was noticed in their mode of distribution.

9. S. E. ¼ sec. 14, T. 6, R. 6 W.—Quite an extensive group, consisting of an animal form, three oblong mounds, and a number of small round mounds is to be seen at this locality. They are situated about half a mile above the Wisconsin River bridge, at Banfill, on a raised, level piece of land, near the foot of the bluff. The land was formerly under cultivation, but not for a sufficiently long time to injure the appearance of the mounds. The effigy-mound is quite large, and appears to be the central figure, around which the others were grouped, and was probably the first earthwork constructed. It is quite large and well proportioned, with the head thrown up and forward and the legs bent forward and backward. It seems designed to represent some animal in a springing or jumping posture. At the intersection of the body, neck, and fore-limbs, a hole was sunk 6 feet long by 3 wide, by Messrs. Rice, Mitchell, Thompson, Haven, and myself. Nothing was found, except that the mound was constructed of a very hard and compact clay, quite homogeneous throughout, and apparently the same as the underlying soil, into which we penetrated about 18 inches.

Abandoning operations on the effigy-mound, we next excavated one of the circular mounds by means of a trench about 2 feet wide, carried in from the circumference to the center on the same level as the adjacent ground. On reaching the center a human skeleton was found, the bones of which were so brittle and crumbling that no perfect ones could be obtained. During the exhumation the following facts were observed. The process of burial had been as follows: The body was seated on the level ground with the face to the west, and the legs stretched out in the same direction, but not separated, the knees not being at all drawn up. The body and head were erect and the arms placed by the sides. The mound was built up around the corpse in this position. Since then the process of decay, by removing the soft internal parts of the body, had permitted all the bones of the skull and body to fall down into and on the pelvis, where most of them were found confused and mingled together, compacted in a hard dark clay, from which the bones were separated with much difficulty. Parts of the tibia, femur, pelvis, ribs, and skull were recovered, together with parts of the jaw-bones, and numerous teeth. The jaw-bones and teeth were in the best state of preservation of any obtained, the teeth being especially so. Several loose teeth were found belonging to the upper jaw, and the lower jaw still retaining most of its teeth. They indicated an adult individual, and were, without exception, flattened and worn smooth on their grinding surfaces.

The clay of which the circular mound was constructed was somewhat different from that excavated in the effigy mound. The upper part of the circular mound for about 18 inches, consisted of a sandy clay, which was easily removed with a shovel alone. All below this consisted of a very compact clay, containing but little sand, so hard that a pick was necessary, and the point would not penetrate more than an inch or two at a stroke. So great was the difference in the compactness of the clay in the two mounds excavated, that it occurred to me that the circular mound might have been stamped or rammed, or otherwise compacted at the time when it was built; perhaps for the purpose of protecting the corpse against the attacks of prowling animals.

I do not think that the most skeptical person could regard this as an intrusive burial of a date more recent than the formation of the mound. It bears no internal evidence of ever having been disturbed; and externally the mound precisely resembles all the others in this vicinity, and hundreds of others in different localities which we are accustomed to attribute to the mound-builders.

10. S. E., ¼ sec. 19 W., ½ of sec. 20, S. W. ¼ sec. 17, S. E. ¼ sec. 18, all in T. 6, R. 6 W.—All these several localities appear to be component parts of one grand chain, series, or procession of mounds. This procession may be said to begin near the residence of Hon. Robert Glen, not far from the line between sections 19 and 30, of T. 6, R. 6 W. The first seen are the four round ones, in the orchard near the house, (Diagram I.) They seem to be in a manner set apart from the rest, as quite a distance intervenes between them and the first long one, and they are the only ones of the circular kind.

Figures 1 and 2 (Diagram I) represent two effigies, slightly different in shape and size. From their appearance on the ground no resemblance to any particular animal could be detected. Pursuing a northeasterly course, quite a remarkable series of long straight mounds is found, effigy and circular mounds being entirely absent.

It will be noticed that the mounds are situated in a continuous line, and not in several parallels, or grouped about, as in some other instances. This line conforms in its irregularities exactly to the crest of the ridge, so that they command an extensive view on both sides of the ridge. These mounds, with one or two exceptions, have all been under cultivation; which has somewhat

Diagram I.

diminished their height and sharpness of outline, but has not otherwise injured them or rendered them difficult to find.

Proceeding along the crest of the ridge, nothing is seen for about half a mile, until the first of the mounds (Fig. 3, Diagram II) is found followed by Figs. 4 and 5 at short intervals. Figs. 3 and 5 are somewhat similar, and not unlike Fig. 2 of Diagram I. Following Fig. 5 is a row of twenty round mounds; each about 25 feet in diameter, 5 or 6 feet high and about 25 feet apart. They are arranged in straight lines, conforming to the crest of the ridge. The long north and south row of eleven mounds, when viewed from the south end, presents a peculiarly striking and impressive appearance. At the northern end of this row of mounds the ridge turns abruptly to the west, and a change in the mounds also takes place. No more round mounds are to be found, but more animal structures, of which may be observed the following peculiar arrangement. As all the effigies at the south end of the circular mounds are headed away from them, so also those at the northern end appear to be departing from them in a westerly direction.

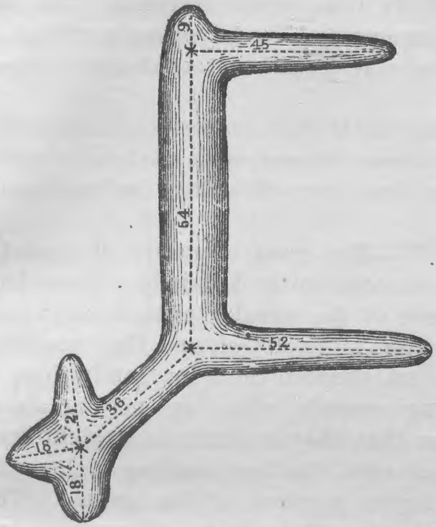


Fig. 3.

Proceeding westward along the ridge, Fig. 7 (Diagram II) is seen, which is reproduced on a larger scale in Fig. 3. The animal represented by this mound appears to have a short tail and horns, and is probably designed to represent some species of deer. It is one of the few effigy mounds in which we can trace a resemblance to some particular animal. It will be seen that its feet are turned to the south, in an opposite direction to all the others. Two hundred feet west of Fig. 7 is Fig. 8, the only long mound in this procession. A long interval now occurs in which no mounds of any kind are found, until at the extreme end of the ridge Figs. 9 and 10 are found. From this point, a beautiful view of the Mississippi and Wisconsin Rivers is obtained.

It will be seen from an inspection of Diagrams I and II, that as the effigies Figs 9 and 10 by themselves close the series on its western end, so is the series in Diagram I closed on its southwestern end by the effigies, Figs. 1 and 2. Whether this is merely accidental, or the work of design, is difficult to determine. There seems to be a certain uniformity of distribution among the mounds on this ridge as if it were an arrangement according to a preconceived plan or custom. It is seen in the location of all the long mounds by themselves; the same is the case with the circular ones, and the effigies also are located in groups. Nor does the presence of the long mound, Fig. 8, Diagram II, or the round ones near the residence of Mr. Glen appear to conflict with the general unity of design; as the former may have served some special or temporary purpose, and the latter may have been constructed subsequently to the rest.

The mounds represented on Diagram II, have never been cultivated, but most of them are situated in almost impenetrable thickets of brush and young timber, which renders them very difficult to find and trace out.

11. N. E. ¼ sec. 17, T. 5, R. 6 W.—The group or groups of mounds, represented in Diagram III, are situated on the Mississippi River bottom. They are the first specimens of the circular mounds anywhere observed. Their diameters vary from 20 to 50 feet, and they are from 5 to 15 feet high. The mounds are situated on a low sandy ridge, a few feet higher than the adjoining grounds, which are not far above high-water mark. It will be seen that they are built in straight lines consisting of three or four mounds each, the lines making angles with each other, to conform to the higher portions of the ground. The mounds appear to be constructed of a sandy loam, although, as no excavations were made, it is impossible to say of what material the inside is composed.

In two or three of the mounds near the southern end of the group, excavations had been made which were evidently of a recent date, probably within a few months. The excavations were shallow holes, about 18 inches deep, sunk in the tops of the mounds; a large quantity of human bones and teeth had been exhumed from them in each instance. They were still lying scattered about on the summits of the mounds, and a number of them were collected. The bones were well preserved and firm in their texture, and the teeth, some of which were as sound and solid as any in a living person, had the grinding surfaces worn flat and smooth, similarly to those before mentioned.

The fine state of preservation of the bones, so different from those found in the mound previously described, together with the circumstance of their being found so near the surface, leads me to think that they are not the bones of the original mound-builders, but rather that they are intrusive burials; that these mounds have been resorted to in comparatively recent times by a different race for burial purposes. Unfortunately no crania (except some small fragments) were found, which might have been of assistance in determining this question; and my limited time did not permit me to make any excavations.

12. S. E. ¼ sec. 17, T. 5, R. 6 W.—Following the course of the Mississippi about a quarter of a mile southeast of the preceding locality, numerous long mounds were seen arranged in several rows parallel to each other and to the river. They are situated in the cultivated fields

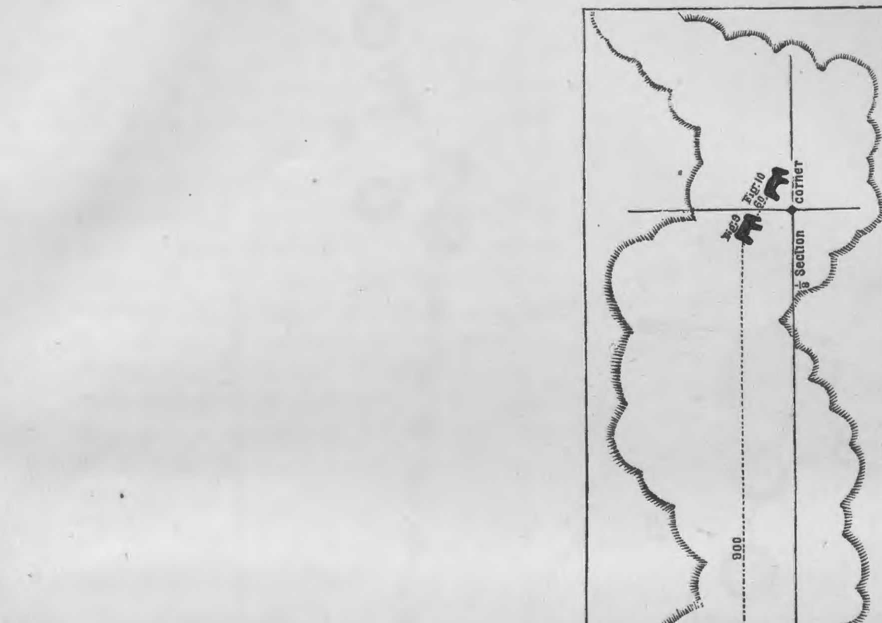

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DIAGRAM II.

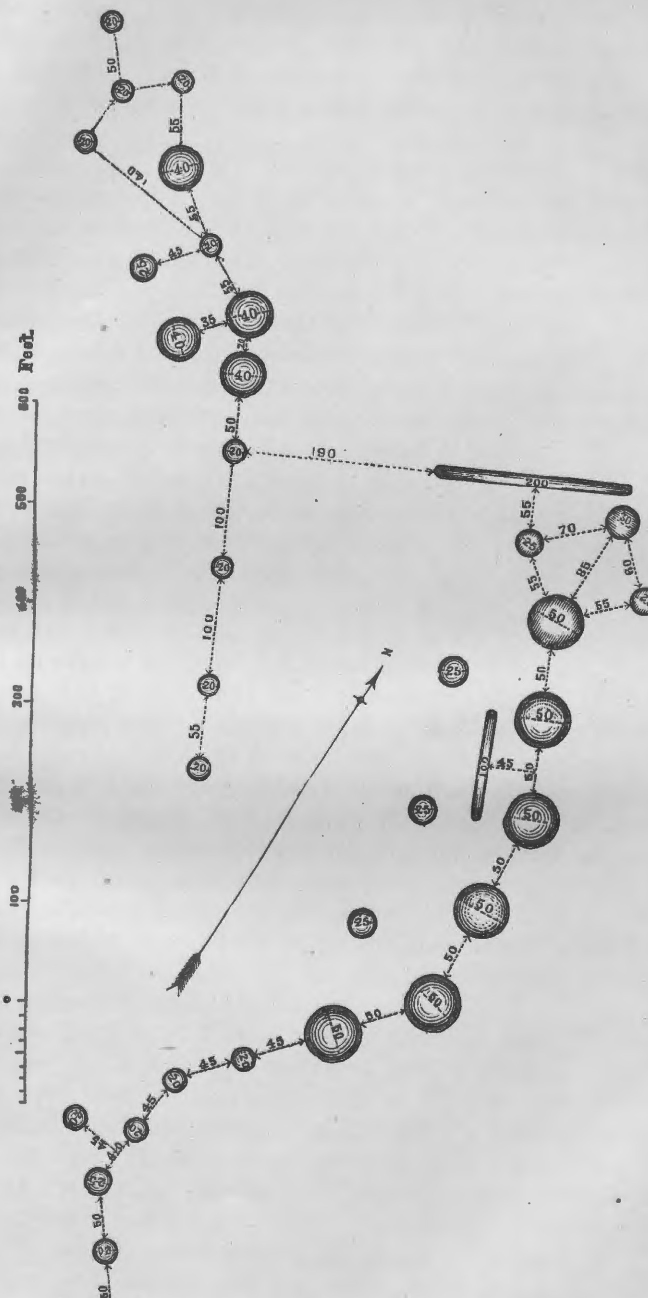


DIAGRAM III.

and are nearly obliterated. At the time these localities were visited the valley was covered by a crop of standing corn, which rendered it difficult to find them, and it is probable that many exist which were not noticed. No circular or effigy mounds were found in connection with them.

13. S. E. ¼ sec. 21, T. 5, R. 6 W.—Continuing down the valley we come to a group in which the three kinds of mounds are well represented. They lie upon the alluvial bottom, quite near a bayou of the Mississippi, and none of them are more than 8 feet above high-water mark, while those in the southern part of the group are not more than 3 feet. In this group, where all kinds are represented, there seems to be a separation of the long and round mounds from each other. There is nothing of peculiar interest in the occurrence of the long and circular mounds, but we have here two quite singular effigies. The central one of the group is evidently intended to represent a bird with the wings spread, in the act of flying; the head is directed to the south. The wings measure 94 feet each way, from the center of the body to their extremities, and the length of the tail is 65 feet. It is quite a large and well-formed effigy, and is different from the other bird mounds in having an angle in the wings.

Situated at the northern end of the group is the most interesting effigy-mound anywhere observed. A description of it by Mr. Warner, of Patch Grove, was published in the Smithsonian report of 1872, page 416. It is known as the "Elephant Mound," and as it lies upon the ground it resembles an elephant or mastodon much more closely than any other animal, and the resemblance is much more perfect in this instance than in other effigies. This mound, in common with all the rest in the group, has been under cultivation; and on account of its size special efforts have been made with plows and scrapers to bring it to the level of the adjacent field. Its size alone has protected it. These efforts have resulted in diminishing its height, increasing its width and general circumference, and rendering its outline somewhat indistinct, so that it was difficult to make exact measurements.

14. N. E. ¼ sec. 17, T. 3, R. 5 W.—A short distance below Cassville, near the bank of the Mississippi, are three animal mounds. Several long mounds were seen in the vicinity but no circular ones. One of them is probably intended to represent some kind of a lizard or saurian, another is a bird with extended wings, and the third is uncertain, but, in common with the first, is remarkable for having a round head, a peculiarity not observed in any other effigies. The first-mentioned is a large and symmetrical mound, and is the only one of the kind observed. The mounds are very well defined, and are some of the best-preserved effigies seen.

15. S. ½ sec. 30, N. E. ¼, sec. 31, N. W. ¼, sec. 32, T. 3, R. 4 W.—This is a long, high ridge, having its general direction a little south of east. Upon it is the most extensive representation and fullest development

of the mound system anywhere observed. Circular, straight, and effigy mounds extend along the crest of this ridge for a distance of nearly two miles in uninterrupted succession. The mounds are so extensive and numerous that my time did not admit of making even the most general survey of any but the effigies. One of them is a perfectly symmetrical cross, the opposite parts corresponding exactly in length. It is difficult to conceive what its object could have been, or of what it is symbolical. Another, from its long tail, slender body, and small head, may have been designed to represent some one of the feline species. A third and fourth exhibit quite a remarkable formation in the extremities of the limbs.

Civilization has not as yet encroached on this locality, except to a slight extent at the eastern end, which is beginning to be cultivated. Most of the earthworks are doubtless in the condition in which they were left at the time of their desertion by their builders. It is probable that in a few years all the land will be under cultivation, and the mounds obliterated. Perhaps a few dollars would be judiciously appropriated in making these grounds—burial grounds, perhaps—the property of some scientific society, and thus preserve them from further destruction.

From observations of the mounds at all the foregoing localities, we arrive at the following conclusions in regard to their distribution:

1. The circular mounds are frequently found in one locality and the long mounds in another; or if both kinds are found in the same group they are usually separated.

2. When the number of mounds does not exceed five or six, they are usually of the same kind.

3. The effigy mounds are never found unaccompanied by either long or circular mounds, and are usually attended by both.

4. All the mounds appear to have been made by scraping up the surface soil; either from the ground immediately adjacent or from a neighboring hill. In no place was any appearance of excavation seen.

5. During the Champlain period the valley of the Mississippi underwent a depression of at least 50 feet, during which period it was filled with a stratified drift, of which occasional patches still remain along the sides of the bluffs. To this there succeeded a period of elevation, in which most of the valley drift was removed. The situation of some of the mounds so near the present high-water mark shows that they were not built until after the completion of the last elevatory movement, which probably took place within the recent period.

The mounds themselves reveal that order and government must have prevailed to some extent among the race which built them, but afford no clew to the time in which they lived.

DEPOSITS OF FLINT IMPLEMENTS.

By J. F. Snyder, M. D., *of Virginia, Cass County, Illinois.*

The custom of concealing in the ground surplus articles of food, apparel, weapons, &c., for temporary safe-keeping, is common to all nomadic tribes. On this continent it was practiced by the pre-historic races, was in vogue among the Indians first observed by Europeans, and is still the method by which the hunter-tribes of our western territories preserve such property or stores as cannot be readily transported in their hunting expeditions or are not wanted for immediate use. The anonymous Portuguese chronicler of De Soto's expedition to the Mississippi makes mention of this custom prevailing among the Indians of that day; and we read in Strachey,* "Their corne, and (indeed) thire copper, hatchetts, howses, beades, perle, and most things with them of value, according to their owne estymacion, they hide, one from the knowledge of another, in the grownd within the woods, and so keepe them all the yeare, or untill they have fitt use for them, as the Romains did their monais and treasure in certain cellars, called, therefore, as Plinye remembers, *favissoe;* and when they take them forth they scarce make their women privie to the storehouse."

The early French "voyageurs" and traders among the Indians soon learned from them the advantages and security of this sort of storehouse, and frequently had recourse to it, and cached provisions, ammunition, or other stores too cumbersome to carry along with them, or which they intended to secure from beasts and Indians, as reserves for future use. Many of their deposits were never recovered. In some instances they were forgotten; in others, the persons making the cache returned by some other and remote route; and in some cases they so effectually obliterated all external signs of their subterranean storehouse that they were unable to find it again.

The same ideas and the same mishaps occurred to the ancient occupants of our country. The same necessities in life are apt to suggest to the human mind in all localities, in similar circumstances, identical or analogous modes of relief. The motive of the aborigines for hiding in the ground stores of weapons, implements, and utensils is plainly discernible in a large majority of their ancient deposits. It was simply the safe-keeping of the property for future use. The ground was their only liable repository. The builders of the mounds frequently stored in the earth many perishable articles of which we now find but slight traces or none at all, there remaining, in these primitive storehouses, such objects alone as were wrought from more durable materials. Of this class of deposits—the ordinary ancient cache—I will give

* The Historie of Travaile into Virginia, Britannia; by William Strachey, printed for the Hakluyt Society.

a few instances before referring to certain extraordinary deposits of rare and peculiar flints.

A few years ago, at Bluff City, in Schuyler County, Illinois, some hogs confined in a pen, at the foot of the bluffs, rooted out of the ground a deposit of sixteen stone axes or celts, all of which bore marks of considerable use. They were made of hard, compact diorite, and varied in size from 6 to 16 inches in length and from 2 to 7 inches in width. Considering the probable uses to which these tools had been applied, and the location of the deposit, in a spur of the bluff near the (Illinois) river, it was plain that here, in ages past, a canoe had been constructed. The work completed, the tools were cached at the foot of the bluff, until they should again be needed for similar work.

The finest Indian mound in the State of Illinois is situated three miles northeast of the town of Lebanon, in Saint Clair County, not far from the western border of Looking-glass prairie. In shape it is a truncated pyramid, or rather a parallelogram, measuring at its base 400 feet in length and 250 feet in width, and rises in perfect proportions to the height of 50 feet. The angles are still sharp and well defined, and the top level, comprising (approximately) an area of 80 by 150 feet, which doubtless served as the base of some elaborate wooden structure.

In the summer of 1843 the proprietor of the land, Mr. Baldwin, in sinking a well near one corner of the mound, found, a few feet below the surface, packed closely together, eighteen large flint spades. These implements were broad flat pieces of white or grayish-white flint, measuring, the smallest 9 inches in length by 5 inches in width; the largest, 15 inches by 7. They are nearly an inch in thickness in the middle, neatly chipped to an edge all around, flat on one side and slightly convex on the other. One end of each flint is broader than the other, and the broad end is symmetrically rounded, and polished as smooth as glass by long-continued use in sandy soil. The narrow end is rough and not so neatly finished, showing no marks of wear, and was in all probability, when the implement was in use, fastened in some sort of handle. It cannot be doubted that these flints were in part the tools used in making the mound; and when the great work was finished, they were stored away in the ground until again needed.

Prof. Charles Rau, in the Smithsonian Annual Report for the year 1868, (pp. 401–403,) gives an interesting account of a deposit of agricultural flint implements and other objects found in the grading of a street in East Saint Louis, Saint Clair County, Illinois. The specimens from that deposit, as stated by Professor Rau, show no marks of wear, and were probably never used, but constituted the stock in trade of some enterprising artisan or trader who utilized the sand-bank for a warehouse and place of safety for his merchandise. The same author, in the Smithsonian Annual Report for 1872, (pp. 402–403,) describes a deposit of hornstone disks, almost circular in shape, which were found in the southeastern portion of the same county, in the summer of 1869.

They were buried near the bank of a small ravine, within a few miles of the Kaskaskia River; and, from the wear and hard service of which they bear signs, it is inferred that they constituted a "kit of tools" cached until further needed.

The author of "Antiquities of the Southern Indians" informed me that he has frequently found these disks also about old Indian camping-grounds, along the water-courses of Georgia. Consequently they must have been tools in common use by tribes inhabiting a wide range of territory.

The deposit briefly noticed, on the authority of Dr. P. R. Hoy, in Lapham's "Antiquities of Wisconsin,"* consisted of about forty disks, scarcely differing in any respect from those last mentioned, and exhibiting the same unmistakable indications of hard usage. One of these flints from a peat-bog near Racine, Wis., was given to me by Dr. Hoy, who told me that the specimen, though equal in size to any of the forty others found with it, was different in shape from the rest, having one end broader, while all the other specimens were nearly round or oval.

Mr. John P. Jones, of Keytesville, Chariton County, Missouri, communicated to me some particulars of three deposits of flint implements which at various periods of time were brought to light in the neighborhood of his home. The first was a store of spear-heads and arrow-points, several hundreds in number, which he was too late to secure or satisfactorily examine. The weapons were all new, a fact conclusive that here had been the arsenal of a tribe, or the secreted stock in trade of another primitive American merchant. Better fortune attended Mr. Jones in the discovery of a second deposit, consisting of seventeen new flint knives, as the greater number of them fell into his possession.

A third deposit, described by Mr. Jones, was discovered in the valley or "second bottom" of the Chariton River, and contained about fifty small, flat, ovoid, pointed flints. They had been stuck into the ground, point down, in concentric circles, and were then covered with earth, forming over them a low, flat mound 12 or 18 inches in height by 5 or 6 feet in diameter. These implements had been in use for a long time before receiving their final interment. Some were gapped on the edges, and all were to a certain extent polished.

The deposits of stone implements in the ground, to which I have referred, are but a few representative instances of the kind from a great number discovered in all parts of the United States. In the cases I have cited, the intention of the person making the deposit is at once apparent. The property was placed in the ground to hide and thereby to secure it. Those implements found which bear the marks of use are such as were not at the time needed, and were hidden away until again wanted, or for safe-keeping during the temporary absence of the owner. The new or unused articles, it is presumable, were the stores of traders

* Published by the Smithsonian Institution. 1855. Pp. 8 and 10.

or manufacturers who deposited their wares in the ground to conceal them until they could dispose of them to advantage.

In the "Ancient Monuments of the Mississippi Valley" is mentioned a strange class of deposits of stone implements and other objects, differing in the motive of interment from the simple caches which I have described. The interest of that valuable work culminates in the chapter devoted to "sacrificial mounds," the arrangement and contents of which exhibit the plane of religious thought attained by the mound-builders. The "altars" of burnt clay; the votive offerings, through fire, of their choicest works in stone, copper, mica, and shell, doubtless together with many articles of less durable materials which were consumed by the intense heat; the cremation of human bodies; the heaping of earth upon the glowing mass; and the introduction of strata of sand in the enveloping tumulus, with the outward covering of coarse gravel, together constitute a record wonderful and unparalleled. Certainly the most plausible solution of this interesting problem rests in the view ascribing the origin of this class of monuments to ideas of propitiation or devotional fanaticism. In either case we feel tolerably certain of the fact that the inclosures of the so-called sacrificial mounds were intended by their constructors to be final. We have here no stores of hidden goods to be withdrawn at pleasure, for use or traffic, but a deposit of objects made in accordance with some superstitious rite or religious notion, and designed to remain there undisturbed to the end of time.

Associated with the sacred mounds which covered the burnt offerings, and in the same inclosure, Squier and Davis, (page 158, *l. c.*) describe one which contained no burnt altar, but in the place of it a great number of curiously-wrought disks of black flint, which appeared to have been buried without the accompaniment of fire, but with the same precision, and covered by the same strata of sand and outward layer of gravel as were the clay altars of the other mounds with their treasures of polished implements, utensils, and ornaments. The account given by Mr. Squier of this deposit, on page 158, "Ancient Monuments," &c., is as follows: "Another singular mound, of somewhat anomalous character, of which a section is herewith given, occurred in the same inclosure with the above. It is remarkable as being very broad and flat, measuring at least 80 feet in diameter by 6 or 7 in height. It has two sand strata, but instead of an altar there are two layers of disks chipped out of hornstone, some nearly round, others in the form of spear-heads. They are of various sizes, but are for the most part about 6 inches long by 4 wide, and three-quarters of an inch or an inch in thickness. They are placed side by side, a little inclining, and one layer resting immediately on the other. Out of an excavation 6 feet long by 4 wide not far from six hundred were thrown. The deposit extends beyond the limits of the excavation on every side. Supposing it to be 12 feet square, (and it may be 20 or 30,) we have not far from four thousand of these disks deposited here. If they were thus placed as an offering, we can form some estimate, in view of the fact that they must have been brought from a great distance and fashioned with great toil, of the devotional fervor which induced the sacrifice, or the magnitude of the calamity which that sacrifice was perhaps intended to avert. The fact that this description of stone chips most easily when newly quarried, has induced the suggestion that the disks were deposited here for the purpose of protecting them from the hardening influences of the atmosphere, and were intended to be withdrawn and manufactured as occasion warranted or necessity required. It is incredible, however, that so much care should be taken to fashion the mound and introduce the mysterious sand strata, if it was designed to be disturbed at any subsequent period. There is little doubt that the deposit was final, and was made in compliance with some religious requirement. An excavation below these layers discovered traces of fire, but too slight to be worthy of more than a passing notice." It may be here noted that the disks in this deposit had never been used.

In the year 1860 a similar deposit of hornstone disks was discovered in this vicinity, in the town of Frederickville, in Schuyler County, on the west side of the Illinois River. This locality was a favorite abiding-place of the Indians, and the center of a dense population. Relics of their works are still found in abundance throughout this region. A small ravine near the foot of a bluff, one day, after a heavy rain, caved in on one side, and the displacement of a large quantity of earth in consequence exposed to view a few strange-looking flints. They had been buried about 5 feet below the surface of the hillside, laid together on edge, side by side in long rows, forming a single layer of unknown extent. The discovery of such novel objects attracted some of the villagers to the place, who dug out about *thirty-five hundred* of the unique implements, and, their curiosity satisfied, abandoned the work without reaching the limits of the deposit. From diligent inquiries of persons who were present at the time, I learned that the flints had apparently been placed in an excavation made for the purpose at a point of the bluff above the highest water-level, and about two hundred yards from the river-bank. No traces of fire above or below were seen, and no peculiar arrangement of the superincumbent earth was noticed, nor was any mound or other mark of any kind discernible over or about the place to designate their hiding-place. It was several years after this occurrence when, in 1871, I first heard of it. Several visits to the place were rewarded with but a few badly mutilated specimens of the disks which I obtained from the citizens; the rest of the large number had disappeared. At length I found in the possession of Mrs. Charles Farwell (whose husband owns the premises where the deposit was found) ten of the flints, two of which she kindly gave me. The stone of which these disks are made is a dark, glossy hornstone, undistinguishable from the disks of the sacrificial mound in Ohio, and, like that deposit, these Frederickville flints had been buried without having been used.

On the eastern bank of the Illinois, below the confluence of the Sangamon River, and four miles below Frederickville, is the city of Beardstown, in Cass County. Immediately on the bank of the river at this place can yet be seen the remnant of a large mound of artificial construction, which formerly rose 30 feet or more above the level of the surrounding country, and afforded from its summit an uninterrupted view for miles up and down the river. This fine monument has succumbed to the progress of modern civilization, and almost entirely disappeared.

In the summer of 1872, I received intelligence that a deposit of the same sort of flints had been found at Beardstown. In excavating a cellar for a new building on Main street, the laborers had reached the depth of 4 feet, when they struck the flints, and soon threw them all out, about a thousand in number, a large portion of which I secured. The disposition of the flints in this deposit was different from that in the Ohio mound, and that of the Frederickville deposit also. These were imbedded in the bank of the river, above the reach of highest water, and about 300 yards up the bank of the stream from the large mound. An excavation about 5 feet deep had been made through the sand to the drift-clay, and, instead of being placed on edge, as in the two other deposits, a layer of the disks had been placed flat on the clay, with points up stream, and overlapping each other as shingles are arranged on a roof. Over the first layer of flints was a stratum of clay 2 inches in thickness; then another layer of flints was arranged as the first, over which was spread another 2-inch stratum of clay, and so on, until the deposit comprised five series or layers of flints, when the whole was covered with sand. The area occupied by these buried flints was an ovoid, corresponding in outline with one of the implements, and measured in length about 6 feet, and in width 4 feet. But the apex, estimated to be one-third of the area, was cut off by the cellar-wall of the store-house which been erected there twenty years previously to this date. On inquiry I learned from an old citizen who was present when the cellar was dug, that the deposit of flints was then discovered, and about five hundred of them were thrown out; and that the discovery at that time attracted but little attention, "for," he remarked, "Indian flints and stone axes were as common here then as brick-bats are now." No traces of fire were visible, nor had there been within the recollection of the oldest settler of the place any mound or other external object to mark the place of deposit. The flints from this lot are identical in material, color, style of execution, and general outline and dimensions with those I have seen from the deposits at Frederickville and Clark's Work in Ohio. None of these bore any marks of wear or use. A few of them are almost circular in shape. Some are rough, but the majority are very accurately proportioned and neatly finished, which we may accept as proof that the implements were manufactured by several artisans, who possessed unequal degees of skill. Their average length is 6 inches, their width 4 inches, and they are three-fourths of an inch thick in the middle. Their average weight is one and a half pound. The fixed pattern which they are all intended to approximate is an ovoid with pointed apex and regularly curved base. Many of them are flat; others are a little concave on one side and convex on the the other, though a very large majority of those I have examined are equally convex on both sides, and all are carefully chipped to a sharp edge all around. They were all made from globular or oval nodules of black or dark-gray hornstone, which were first split open and each part again split or worked down by chipping to the shape and size required. In several of the specimens the first fracture of the nodule forms the side of the implement with but slight modification beyond a little trimming of the edges. Many of them retain in the center the nucleus around which the siliceous atoms agglomerated to form the nodule. In a few the nucleus is a rough piece of limestone; in others it consists of fragments of beautifully crystallized chalcedony, surrounded by regular light and dark circles of eccentric accretion, and the exterior of the rock was encrusted with a compact, drab-colored calcareo-siliceous coating half an inch in thickness, which in some of the specimens has not been entirely removed. Nearly all the Beardstown disks were roughened and discolored with patches of calcareous concretion almost as hard and solid as the flint itself, indicative of undisturbed repose in their clay envelopes for a great period of time. The raw material of which these objects were wrought was imported from some locality remote from their hiding-place. An Illinoisan myself by birth, I have nowhere in this State, during thirty years' observation of its geology, found any number of hornstone nodules in any of its strata. Among the disks of the sacrificial mound at Clark's Work, Ohio, nodules of hornstone were found,* but none, so far as I could ascertain, were met with in the Frederickville deposit, and I am certain there were none with the Beardstown flints. The nodules of hornstone found buried at East Saint Louis, near the deposit of agricultural flint implements,† are the same in texture and color as all the disks. Nodules of this variety of flint, I am informed, are quite common in some parts of Indiana, and I have often seen them in Southwestern Missouri.‡ Mr. Squier thinks the Ohio disks drew their supplies of flint from a locality known as "Flint Ridge," which extends through Licking and Muskingum Counties in that State. "This ridge," he says, "extends for many miles, and countless pits are to be observed throughout its entire length, from which the stone was taken. These excavations are often 10 or 14 feet deep, and occupy acres in extent."

The buried flint nodules of East Saint Louis are the only ones of the

*Ancient Monuments of the Mississippi Valley, chapter xiii, page 214.

† Smithsonian Annual Report for 1868, page 403.

‡ See remarks on "Old Diggings," pages 98 and 205 of 1 and 11 Annual Reports of the Geological Survey of Missouri, by G. C. Swallow, State geologist, Jefferson City, 1855.

kind I have ever heard of in this State. In all my hunts for Indian relics I have met with no such masses of flint here; nor have I seen any place where fragments or "chips" of this stone would indicate, by their quantity, the site of a workshop that turned out hornstone disks from the crude bowlders. Consequently, I infer that the buried implements of Frederickville and Beardstown were imported ready made, and not manufactured in this region from imported masses of stone.

Unlike all other stone implements, these have been found only in large deposits, singularly uniform in size, material, shape, and workmanship, and presenting the further remarkable feature of being buried new; thus far not one of them having ever been found isolated or bearing marks of use.

A deposit of flints, somewhat approaching the disks in size and shape, was found a few years ago near Trenton, N. J. Dr. Abbott, who described them in the American Naturalist (vol. iv, 153–5) and previously in the Proceedings of the Academy of Sciences, Philadelphia, (1863, page 278,) styles them "hatchets." His description of them in the Naturalist is as follows: "Prominent in this list stands the magnificent brown jasper specimen, (Fig. 22.) There we have a carefully-chipped hatchet, well edged on all sides, of a nearly perfect oval outline. Its greatest width is 3¾ inches; greatest length 6 inches, and its greatest thickness scarcely ¾ of an inch. This specimen is one of a hundred and fifty that were discovered in plowing a piece of newly-drained meadow near Trenton, N. J. The one figured is somewhat shorter and broader than the others, which might have been hatchets or lance-heads."

The description and drawing given by Dr. Abbott in the Naturalist, would answer well for many of my Beardstown disks; and the similarity of the two sets of implements is strengthened by the parallel fact that none like his have as yet been found isolated.

The explanation first suggested to account for the astonishing number of flints in the sacrificial mound at Clark's works, was that it constituted merely a magazine of "roughly blocked-out spear-points," convenient to be withdrawn and finished at leisure, and buried, in order to keep the stone damp and the more easy to chip. But this hypothesis fails to account for certain peculiarities of their occurrence. For what purpose they were made, and why buried in such vast numbers and with such care, are points yet undetermined.

Among these flints, occasionally one is found longer and narrower than the others, and very much resembling in form some of the flint hoes used in the cultivation of maize by the Indians down to the days of the early French missionaries.* It is probably this chance similarity which has led Dr. Patrick to regard all the hornstone disks of the three deposits as agricultural tools. If they were designed for agricultural implements, or for weapons of war or the chase, or for tools to be used in any of their mechanical arts, it is evident that they had not yet passed

* Du Pratz "Histoire de la Louisiane." Paris, 1758. Vol. ii, p. 176.

into general use, as all yet discovered were new, and none have been found isolated, as we find specimens of all other objects of stone used by the people, who we feel certain also made and deposited the disks.

The most rational theory in explanation of the disks in the mound at Clark's Work is, that they were deposited there in obedience to some superstitious or religious idea; especially when viewed in connection with the strange contents of the other mounds in the same inclosure. But why similar disks, which we have the best reasons to believe were from the same locality and made by the same people, should be transported to the banks of the Illinois River, and there receive final entombment, is not so easy of interpretation.

Until further research has thrown additional light upon the origin and design of these curious flints, they are entitled to be ranked among the most interesting and problematical of aboriginal stone implements.

ANCIENT MICA MINES IN NORTH CAROLINA.

By C. D. Smith, *of Franklin, N. C.*

Among the remains found in the mounds of the Mississippi Valley, mica has been mentioned. While some of it was perhaps used for ornamental purposes and as mirrors, it is a probable conjecture that it was largely used in the religious rites of the mound-building race. That found over the faces, or breasts, or over the whole skeletons had, no doubt, attached to it something sacred in the minds of the race. The supposition that much of the mica found in those ancient mounds was employed in the religious ceremonies of the race, suggests the high value placed upon it, and the immense labor employed in procuring it, as well as the great distance to which it was transported, sustain the idea that there was more than an economical or commercial value attached to it.

Prof. Charles Rau suggests that the mica found in the western mounds was probably obtained along the southern spurs of the Alleghanies. This is, I have no doubt, correct. For here we have ancient diggings which were open excavations. Some of these excavations are of large proportions, and must have employed a large force and a series of years in their accomplishment. I have not seen the slightest trace of mining work for any metallic substance or ore. There are a great number of these ancient excavations, and they were evidently all made in mining for mica, with the exception of a few made in soapstone beds, where the aborigines no doubt obtained the material for their stone pots. The largest of the excavations in steatite which I have seen are in Tallapoosa County, Alabama. There are several ancient mica diggings in Mitchell County, North Carolina. Gen. T. L. Clingman, some twenty-five or thirty years ago, supposing that these old diggings were the work of De Soto in search for silver, had one of the old pits opened, and instead of finding silver, he found a vein containing large crystals of mica. When mica was brought into use among us and assumed an economic value, subsequent working on the vein settled the question as to the object of the ancient miners. This mine has been a very profitable one. There are several other old diggings in Mitchell County, some of which have been opened and valuable mica veins found in them. It is manifest that the ancient miners understood their business well. Indeed, they seldom committed a mistake. In every instance which has come under my observation, where they did work along the mica zone, mica veins have been found by opening the old works. It is also a noteworthy fact that where the old excavations are extensive, the veins yield usually large crystals of firm mica of good cleavage and in every way of excellent quality. The mica that they procured in their mining operations has been removed except the refuse, such as our people generally reject. I have one case to the contrary. In that case the mica had been taken one hundred feet perhaps and buried. It was found to the amount of several cart-loads. It had been packed down with great regularity in an excavation. In this county (Macon) there are a dozen or more of these old diggings known to exist. Most of them have been opened within the last six or seven years and operated upon by our present mica miners. I have had two of these old works opened, one of them upon my own farm. I have watched the developments in these ancient excavations with unusual interest, and I think I see very clearly corroborative evidence that the people who did this ancient work had no implements superior to stone. They only operated upon such veins as contain a decomposed and consequently soft feldspar.

I have observed another interesting fact. Wherever there was a hard point in the vein they worked over it, and then descended again. If they had known the use of metallic implements, it seems that they would have removed such points. The ancient works on my own farm are the most extensive I have yet seen, and are therefore worthy of description. The vein, as I have proved by my drifting upon it, has a general strike of N. 73° W., S. 73° E. So far, however, as I have drifted upon it, it runs in a zigzag along this general strike. The old excavation commences at a small branch and runs at a right-angle from it into a ridge that juts down with a gentle slope. The dump-material has been thrown right and left for the first hundred feet. I tunneled in diagonally and struck the vein 60 feet from the branch, and have drifted along it 40 feet. Here we reach an immense dump-rim, 65 feet higher than the level of the branch, and which seems to have been thrown back upon their works. It forms at this end a circular rim to the continued excavations higher up the ridge. The whole length of the excavation from the branch to the upper end of the cut is about 320 feet. The material removed from the upper part of the cut was carried up the hill as well as down it. The dump on the upper side of this upper part of the cut, and at the widest point, is about 25 feet above the present bottom of the excavation, and at this point dump and excavation measure about 150 feet across. At the upper end of my tunnel the old digging has been carried down about 30 feet below the surface. If the excavation at the point just mentioned was carried as deep as the work at the upper end of the tunnel, it would make the dump-heap on the upper side 55 feet higher than the bottom of the old works. I have been thus particular, in order to show that with mere stone implements it must have required a series of years and a large force to have accomplished such results.

I shall make special mention of but one other of these old diggings in this county. The vein, as recently worked by the Messrs. Brooks, yielded excellent mica that was of peculiar interest because it contained in every crystal internal markings in deeper and lighter shades of the coloring matter showing the hexagonal form. It has the appearance of having been photographed in the plates of mica. I found one crystal in possession of the proprietors that was revolved upon itself, which, being split up and adjusted, formed a hexagonal crystal and showed the entire hexagonal in the internal markings. May we not suppose that such markings deeply impressed the idolatrous race who used it?

The ancient miners seldom attempted tunneling after the mica, and where there is any evidence of such work it is more like burrowing in than cutting a tunnel. There is one such hole a few miles from Franklin, but it does not exceed 15 feet in length. In one of the old diggings, about four miles from Franklin, an old shaft was discovered and opened last spring, at the bottom of which two irons were found, evidently the shanks of a windlass, an old Spanish ax, and an iron gad. This work was done, perhaps, by De Soto, as his journal leaves us to infer that he passed through this mountain region. Moreover, the pick-marks in this old shaft have sharp angular outlines which distinguish them from the blunt marks of the stone implements as seen in the old diggings. This shaft was assuredly not the work of the race who made the excavations.

A DOUBLE-WALLED EARTHWORK IN ASHTABULA COUNTY, OHIO

By Stephen D. Peet.

There is in Ashtabula County, Ohio, an earthwork which has some distinguishing peculiarities. It consists of a double-walled circle, erected on an elevation of land near Pymatauning Creek in Wayne Township. It is known in that vicinity by the name of "The Fort." It covers only a portion of the so-called island, but the walls run along the contour of one end, while the land on the south extends on the same level to twice the area on the outside. The height of the elevation is but 8 or 10 feet.

It was formerly surrounded by a marsh or bayou of the creek, but this is now underdrained and tilled.

A beautiful growth of beach and maple is found on the island, and trees two feet in diameter stand in rows upon the ridge of the earthwork. The banks gradually rise from the lowland, and the approach to the wall is easy, over a plane on a level with the inclosure. There are two walls and three ditches. The outer wall is 5 feet high from the bottom of the outside ditch. The inner wall is but about 2½ feet in height. The outside ditch is 2½ feet deep from the level, and the inner ditches are, at present, but slight depressions. The width from the outside to the middle ditch is 19 feet, and to the inside, 35 feet in the extreme. From the top of one wall to the top of the other it is 14½ feet. The inclosure contains about 1½ acres, is 250 feet across in one direction and 300 feet in the other. The outer wall extends in a tangent toward the creek, from the inclosure to the water's edge, leaving a space on the water side with a single wall. This space between the two arms of the outer walls extends in a tongue of land which follows a bend of the river, but the length of either arm is but about 100 feet. The whole length of the outer wall, from the water's edge around the inclosure to the water's edge, is about 750 feet. The inclosure was probably a fortification or a stockade. Possibly the inner wall marks the line of the stockade, and the outer wall and ditch may have served for defense; or the inner wall may have served for the protection of those who were behind the outer. It seems most likely to have been a place for permanent encampment. The beauty of the spot is remarkable. The fine growth of forest trees, the meadow across the brook, the occasional copse that dots the lowland on the other side, the gentle slopes in the distance, the massive trees that cover the hillsides, and the running stream stealing around the island and through the meadow, make a lovely spot. It is just the place for a happy and contented Indian community. The fish in the stream, the wild animals in the forest, the fruits of the wildwood, the chestnuts and hickory-nuts that still abound, with perhaps the corn-fields that may have flourished in the vicinity, would furnish food in abundance.

There are discovered on the banks near the island "hearths" or "ovens," which may have been the sites of the tents that were once inhabited by the race now departed. It is probable that the inclosure belonged to the Indians; but to those tribes which roved here long before the white man came. There is no tradition in regard to it, and the natives here at the time of the first white settlement knew nothing of its history.

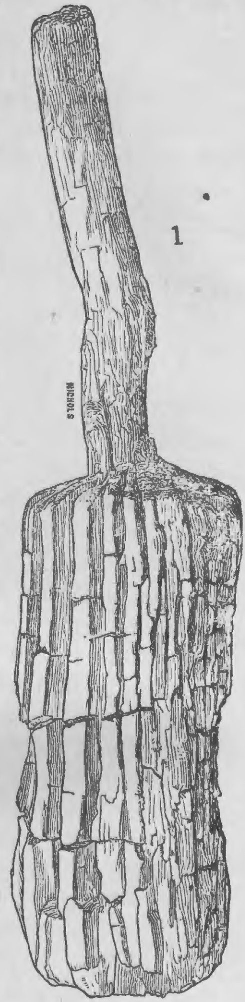
ON AN ANCIENT IMPLEMENT OF WOOD.

By E. W. Ellsworth, *of East Windsor Hill, Connecticut.*

On a mild day, early in December, 1876, I was walking along the east shore of Connecticut River, at a place about six miles above Hartford, where for several years the river has been cutting the bank during seasons of freshet. This eroded bank is from 12 to 15 feet high, measuring perpendicularly upward from the ordinary low-water level of the river. This bank, for about two-thirds its height, measuring downward, is composed of the soft, sandy loam which is the prevailing soil in all our low-lands contiguous to the river. Below this loam, at this particular point, and extending in depth below low-water mark, is a hard bed of blue clay. This clay-bed extends along the shore only a few rods.* I have never seen similar clay elsewhere, near the river. Its most noticeable peculiarity is that it is permeated with vegetable material, which is entirely absent from the loam above it. Stones are very scarce both in the loam and subjacent clay; but the clay is full of leaves, twigs, sticks, roots, stumps, trunks and branches of trees, acorns, and fragments of bark. The larger specimens of wood, which happen to be exposed near low-water line, are sound, smooth, and hard. Some of them, on being cut into, show a grain like pine, although no resin is perceptible in the knots; others are apparently oak. The acorns are very fragile and crumble at a touch. Some fragments of bark are unmistakably from yellow pine. One trunk of a tree shows charring. The larger wood, wherever it has been exposed to sun and air long enough to become partially dried, is scored, cracked, and checked by shrinkage-fissures. I noticed the top of one stump almost as cellular as a honeycomb. Among the smaller material I found slender roots with bud-like projections at long intervals. They were well preserved, but I did not identify them. About two feet above the level of the water, and about one-third imbedded in the clay, the implement of wood which is the subject of this paper attracted my attention. It was evident at a glance that its figure was not one of natural growth, but as a sample of wood its characteristic marks were identical with those of other wood similarly fixed in and projecting from the clay. The ground being frozen, I could not immediately obtain it, but the next day I returned with a hatchet and dug it out. Now that it is thoroughly dried, its weight is four pounds and ten ounces. The shrinkage-fissures have become considerably deeper and more dehiscent since the drying. The handle and head of the mallet are of one piece. The form of the head is approximately a straight cylinder, from the center of one end of which projects the handle, somewhat curved.

*Perhaps the clay-bed extends along the shore below the water-line, and also out into the river. This is the remark of Professor Rau, and is very likely a correct supposition. It has not yet been confirmed nor disproved by exploration.

Illustration No. 1 is a profile view of the implement. No. 2 is a view of the end of the head. The entire length is 21 inches. Length of the head, $11\frac{1}{4}$ inches; length of handle, $9\frac{3}{4}$ inches; diameter of the head, measured in a plane coincident with the curve of the handle, 5 inches; at right angles to that plane, $5\frac{1}{2}$ inches. In the plane coincident with the curve of the handle the middle of the head is indented and battered at two diametrically opposite places, and at those places only, as if by use of the mallet in driving some other tool presenting a surface for impact of not more than 2 or 3 square inches. The diameter of the head through these battered places is 4 inches.* The average diameter of the handle is one inch and a half. It is noticeable that the handle is not season-cracked in proportion to the head. The prevailing color of the head is a reddish-brown, a tint due, in some measure, to the presence of oxide of iron. The handle has been superficially charred, and is mostly blackened thereby, though the brown wood shows through in places. On the head is no trace of charring. The kind of wood of which the implement is made is doubtful. It is often difficult to identify a wood when the weight and color of the sample are so changed as to afford no indications and the normal hardness is uncertain. In the present instance, the structure of the fiber is the only reliable guide. The texture of the sap-cells, both to the unaided eye and with optical helps, is suggestive of white cedar and of spruce. The fiber of the head is straight and free from knots, except one near the handle. In the handle there are two knots, and the fiber mostly follows the curve of that part. The wood is not now harder than white pine, and probably was a soft wood when new.



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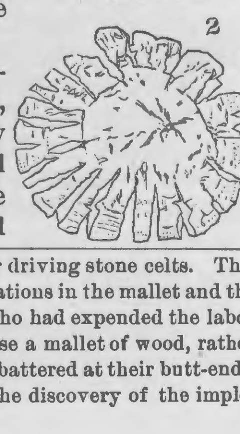

Illustration No. 3 gives some idea of the appearance of the locality of the find. It is, however, sketched from recollection only, as the next day after I obtained the relic snow came and prevented farther examination.† On my first visit to the place, and before I found the mallet, or suspected

* Professor Rau has suggested that the mallet was used for driving stone celts. This is probable, both from the form and position of the indentations in the mallet and the known character of the material in celts. Any workman who had expended the labor necessary to make a celt, would have had the discretion to use a mallet of wood, rather than one of stone, for driving it. Many celts, moreover, are battered at their butt-ends.

† Down to the present date there has been no time, since the discovery of the imple-

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that the *débris* of wood cropping from the clay might be of other than modern growth, one trunk of a tree, which projected over the water at a low angle, just above the water-line, attracted, by its peculiar form, a passing glance. It produced a quick transient impression of having been artificially wrought for some purpose. Being in quest of game at the time, I gave it no thought as to what it was or how it came there. Afterwards I returned to it with awakened interest, and made a careful examination. It projected from the frozen clay, a straight trunk, about 5 feet long and 14 inches in diameter. Its outer end was irregularly broken and splintered. The lower side of the log was of natural cylindrical form, but destitute of bark. The upper side was flattened into a shallow trough, about 10 inches wide, and 3 to 4 inches deep, with flat bottom and flat sides. Take a common wooden lead-pencil and split it along the glued seam; pry out the slip of black lead, and the piece of wood which contained it will resemble the log described. The log would be different in these respects, that the groove would be wider in proportion to its depth, and the edges would be rounded and not sharp. The wood was sound and smooth, and on being chipped presented a grain like pine. If this tree was a windfall and came to its present form and position by natural causes, this smooth, true groove is an anomaly to be accounted for. Timber naturally splits into longitudinal flat sections; not accurately, of course, but approximately. Sometimes, however, a cleft will follow one of the annual rings, in which case a gouge-shaped shell is produced. But a natural cleft that would form a groove with flat bottom and sides, smooth, and free from splinters, would be very rare. A groove formed by decay would present a rough and unsound surface. If, on the other hand, we assume that this groove could not have been fashioned thus shapely by natural cleavage, the theory of human workmanship is not substantiated by any manifest design.

The log being only about 14 inches in diameter, does not contain the necessary timber for a dug-out canoe. It offers some show of human handiwork, and yet the evidence is unsatisfactory. There is no such obscurity about the mallet, whereof the age and origin are uncertain, but not the artificial fashion and design. It is a mallet. Whatever its age may be, it is difficult to evade the evidence that it had a burial coincident with that of the forest growth with which it was associated, and that that forest growth is ancient. At first view, the evidence might appear to be all the other way. What is there along the alluvial banks of this portion of Connecticut River that can tarry long enough to become ancient? Everything within reach of the stream is traveling southward. Any castaway of the farm or factory, if it can float, is liable to come from Vermont or Massachusetts to our shores, to be lodged

ment, when a good view of the locality could be had. The melting of the snow was followed by a rise in the river, and the clay is now below the water-line. In a view, photographically correct, the geological features of the place would be more masked by grass, shrubs, and stumps of modern trees, adhering to sods fallen from the top of the bank.—(March 27, 1877.)

and dislodged, concealed and revealed, at the caprice of the stream. Fences are elusive, trees are vagrant, the soil is erratic. The river has a mortgage on every farm contiguous to itself, and when it purposes foreclosure, resistance on the part of the occupant would cost him more than the value of the land. Within the period of my remembrance, the locality where the mallet was found lay several rods inland from the river-bank. The intervening soil has gone. An island, nearly opposite, of considerable size, and partly cultivated, was carried away by ice in a single freshet. Meantime the opposite shore has advanced upon the bed of the stream. In view of all this shifting, is not the question of antiquity ruled out? Can we have assurance that this mallet has not come, say from Vermont, long since that State was named? We can, and by a plain inference. Everywhere along this portion of the river, wherever bars and flats are deposited, wherever the fluvial forces are constructive, the deposit is homogeneous—the same loamy sand, varying only in this, that in quick water, and at low levels, it is coarse and nearly clean sand; while in the gentlest currents, and at the highest levels, it is the finest loam. In this obvious manner all the erratic soil is graded and shaded. The chief constituents are constantly the same—sand and clay intimately mingled in ever-varying proportions. This material the restless river is forever building up and cutting down; and anything modern, that could once have floated, is liable to be found in it. But the mallet, and the forest growths, the age of which we are considering, have cropped from a bed of clay, having definite outlines and very limited extent; and the migratory loam is superimposed, and has no share in the contents of the clay. The *isolation* of the clay is the insuperable difficulty in the way of regarding it as a river-deposit; and it must be older than the loam, because the law of gravity forbids the growth of such formations except from beneath upward. Clay is assignable to the drift period, when glacial and diluvial forces crushed, carried, and dropped the soil of the continent. Half a mile across the lowlands, east from this clay-bed, in the hill-sides, is clay in place, horizontally laminated, without mixture, perfectly free from organic remains or mineral waifs. The clay in which the mallet was found is a degraded clay, the wash and settle of higher clay in place. In it, the mallet and the tree-growths have been mired and ingulfed. Probably from the clay-hills which are now standing, or from others which have disappeared, rivulets of rain, freighted with mud, and pushing toward a place of drainage, have brought this clay hither. The river did not bring it, but has since brought the loam, and covered the old formation with the new.

My inferences are:

1st. That the isolation of the clay-bed is evidence that it is not a river-deposit.

2d. That the products of vegetation, and other impurities contained in the bed, indicate that it is not clay in place, but that this bed has been washed from neighboring beds by water following a depression leading to the river.

3d. That the intimate mixture of the products of vegetation with the clay, shows that the burial of those products was coincident with the formation of the bed.

4th. That the mallet, having been found partly imbedded in the clay, and having presented characteristic marks of condition identical with those of other associated wood similarly placed, its burial was coincident with that of the other wood.

5th. That the clay-bed, and its contents, are an older formation than the loam, but not so old as the unmixed clay in the neighboring hills.

6th. That the extremely low point in the present valley, at which this clay-imbedded vegetation now lies, indicates that the ancient Connecticut Valley was here somewhat deeper than the present, and that the river has been slowly elevated by soil washed from the highlands and distributed along its course.

7th. That the clay-bed is a landmark, the existence of which proves that the river, however it may have meandered in past ages, has never before run over the locality described since the loam period.

With regard to the preservation of wood, secluded from atmospheric changes in permanently wet soil, the fact that wood so placed will endure indefinitely is too well known and attested to need elucidation in this place.

CENTENNIAL MISSION TO THE INDIANS OF WESTERN NEVADA AND CALIFORNIA.

By Stephen Powers.

ITINERARY.

Under date of August 21, 1875, I was appointed by the Honorable Secretary of the Interior a "special commissioner to make a collection of Indian manufactures, &c., illustrative of Indian life, character, and habits on the eastern slope of the Sierras, and also in California, for the Centennial Exhibition of 1876."

Proceeding on my mission as soon as possible, I arrived at Pyramid Lake Indian reservation, Nevada, September 29, 1875, and remained there four days. This reservation is in charge of the Rev. C. A. Bateman, of the Baptist Church, and contains about 700 Indians, most of whom were absent, by permission, collecting articles of aboriginal food, principally pine-nuts. The reservation, aside from desert wastes, contains about 1,500 acres of irrigable land at the head of the lake. The soil is of a light, sandy character, and is difficult of irrigation, on account of the length of the ditch required, and the consequent evaporation and seepage of the water.

The Indians on this reservation belong to the nation commonly known as the Piutes, (they pronounce it in three syllables, Pi-ú-tes;) but in their own language this branch of them is known as "Coóyuweeweit," from *coóyuwee*, a species of sucker which formerly constituted their principal food-supply. They were not an aggressively warlike race, though in an early day they gave the white settlers considerable trouble, and fought with them some bloody battles. They lived in conical-shaped lodges, constructed of tule and bound with willow wands; they also made of the same material rude rafts, consisting of three bundles of tule lashed firmly together, with which they navigated the lake for fishing purposes. They caught fish with nets of milkweed fiber, with hooks of bone and greasewood fastened to throw-lines, and with bone or horn spears, principally with the latter. To this day the quantity of fish which they take by the latter means is sometimes remarkable. I saw two Indians come in with two large horse-loads, at least 200 pounds, the product of twenty-four hours' labor. In winter Wadsworth affords a ready market for all the fish offered, and a single Indian has been known to sell $25 worth of fish per day for a short time. They were good hunters; but their bows and arrows (partly owing to lack of material) are decidedly inferior to those of the California Indians. They caught a great many hares with nets; and they ate ground-squirrels and ground-hogs; also grasshoppers, crickets, and some other species of insects. I also collected about twenty kinds of seeds and roots which they consumed in their season. The suckers from the lake constituted certainly one-half of their food, game perhaps a quarter, and vegetable products, principally pine-nuts, another quarter.

The men wore breech-cloths of rawhide, deer-skin leggings (in winter) reaching to the groins, and moccasins; the women, waistbands or short petticoats of milkweed fiber, moccasins, long deer-skin dresses, (in winter,) and skull-caps of willow-work.

The Piutes are a well-formed race, with bolder features than those of the typical California Indian, noses more prominent at the root, complexion lighter, and less tendency in youth to superfluous fat. Some of them are wonderfully agile dancers. Most of their games are sedentary, and they are all, both men and women, fatuously fond of gambling. They enjoy practical jokes keenly, and some of their games are comical and produce much laughter. The work of their women is less severe than that of the acorn-eating tribes of California, and they always were and still are much more chaste than the latter.

The present condition of the Piutes is not satisfactory. The prevalence of ophthalmia and blindness among them, owing partly to change of habit and food, partly to filth and venereal disease, partly to unknown causes, is alarming and disgusting. The four reservations in Nevada are without a surgeon, while each of the three in California has one. As above noted, many of them earn large amounts of money in the season by catching and selling fish; but professional gamblers of their own race come down from Virginia City and Carson and play cards with them until the greater portion of it is absorbed. The isolation of the reservation prevents bad white men from visiting it to any extent; on the other hand, the few whites owning hay-ranches along the Truckee set them a poor example of thrift and industry, and, as usual in the vicinity of reservations, are ready to prejudice them against the agent and his subordinates. The enormous amount of sawdust formerly thrown into the Upper Truckee was destructive to the fish; and, on the other hand, the citizens complained that the agent, or the Indians, by his permission, built fish-dams in the river, which totally prevented the fish from ascending from the lake to points where they would be accessible to the settlers. The irrigating appliances have not been managed well; a number of ditches have been constructed or attempted at various times, which began too low down to give the water sufficient elevation to irrigate any considerable amount of territory. Consequently the amount of cereals produced (no vegetables are raised) has been small, and the supply precarious; and the Indians have had to replenish their larders largely from their own resources—from their earnings in the fisheries or from aboriginal products. I judge that not more than half of their yearly consumption has been produced on the reservation.

Many of these Indians labor willingly for the whites, and they frequently solicit and obtain permission to go off the reserve and hire themselves to the ranchmen about Reno and in Carson Valley, or to work in the lumber-mills and chutes, for which they receive from $1 to $2 or $2.50 a day, according to the season and the emergency. Indeed, a very large proportion of the very small amount of agricultural labor done in Nevada is performed by the Piutes. In the towns and mining camps many are employed in washing clothes or washing dishes. A Piute man dislikes to wash clothes, but he will wash dishes quite readily.

The disposition of the whites toward these unfortunate people is generally friendly. Indeed, with the indiscriminate generosity characteristic of the Pacific Coast, there is too much readiness to give them cast-off clothing and fragmentary victuals from hotels and restaurants, instead of furnishing them an opportunity of turning an honest penny by labor. Consequently, numbers of them are seen about the streets of most towns in Western Nevada, in a condition of filth and raggedness, incessantly playing cards—a nuisance and an eyesore.

Hard by, in the suburbs of the town, they have their wretched habitations, consisting chiefly of sage-brush piled up in a circle, and from these they come to town early in the morning, and return at nightfall.

From Pyramid Lake I returned to the railroad, went to Reno, and thence to Susanville, Lassen County, California, arriving there October 6th. There are only a few Indians around this town, and all these belong to Big Meadows and Indian Valley, the aboriginal inhabitants of Honey Lake Valley being now extinct. The line between the Piutes and the California Indians was near the north end of Honey Lake; nowadays the Californians range freely wherever they will, but no Piute dares show himself near Susanville, for, on account of their early atrocities, there are a number of men in the town who have taken an oath to shoot a Piute at sight. The Indians near Susanville are nearly related in language and customs to the tribe living on the Sacramento from Chico to the Cosumnes River, and do not require further description here.

Returning to Reno on the 11th, I remained there and in Carson City three days, to collect articles from the Washoes, though I did not have good success, for they are poor in aboriginal objects. They are a lower race in every respect than the Piutes. They are undoubtedly an offshoot from the California Indians, (being related to them in language,) and colonized Western Nevada by crossing the Sierra from California; but were afterward driven back toward the mountains by the Piutes, who seem to be later arrivals. Their habitat is confined to the Upper Truckee and Carson Rivers, and Lake Tahoe, Sierra Valley, and a few smaller summit valleys north of the latter, though these elevated localities were occupied only in the summer. They were allowed by the Piutes to descend the two rivers for fishing purposes, for a limited season, to a point below their proper boundaries. Although a race of mountaineers, they are darker than the Piutes, shorter in stature, and feebler in battle. Even in winter they seldom had anything that could be called a house, as they lived in a pile of sage-brush, built up hollow and protected on the windward side with skins and blankets. Along the stream, for fishing purposes, they set willow poles in the ground, bend them over, and covered the frame with thatch.

As to their relations with the whites, the remarks above made of the Piutes apply here. They have no reservation, and there are not over 200 of them, a wretched remnant.

On the 15th I left Virginia City for Walker River reservation, and reached it on the afternoon of the next day. There are about as many Indians on this as on Pyramid Lake reservation, but as it is only a subagency it is under the control of a farmer, Mr. George Frasier, who reports to Rev. C. A. Bateman quarterly. The land on this reserve is almost totally incapable of irrigation; at least nothing in that line is attempted except a small garden, which is cultivated by the post-trader. Neither are there any cattle belonging to the reservation, though a great part of it is grazed over by stock belonging to citizens. Notwithstanding these drawbacks the Indians are in a more satisfactory condition than those at Pyramid Lake; they are less exposed to corrupting influences, and are less diseased, and more contented. They are good hunters, and every autumn after the pine-nut harvest is ended they have a custom of organizing a grand rabbit-hunt or drive, in which nearly the whole tribe participate, and hundreds of hares are caught or shot; their flesh is dried for winter consumption, and the pelts are cut into narrow strips and dried to be made into blankets for winter use. This branch of the Piutes is called "Ahgyweit" or "Ahgy-tecitteh," (trout-eaters,) from *ahgy*. This fish is a very important article of their food.

Pine-nuts rank second in importance. Every tribe has its own pine-nut district, on which it is unlawful for another to encroach; for instance, the Carson River Piutes are entitled to all the pine-nuts on Como Hills; those on Lower Walker River to the product of Pine-nut Valley, &c. They frequently cache their supplies in the gravel of a high knoll or hill; it rains so little in Nevada that they receive no detriment.

In the winter and spring they dwell on the high gravelly headlands or the mesas to escape the flooding of the streams and the gnats and mosquitoes; but toward autumn they are accustomed to remove down to the lowlands and make their rude wickiups of brushwood among the shading willows and cottonwoods.

As I said above, the Piute women are accounted comparatively virtuous. Theft also is not so common as among the California Indians. Frontiersmen relate that if they happened to come upon a white man's camp during his absence they would sit down and patiently await his return, lest, if anything should chance to be missing, their tracks might accuse them and bring them to grief, though innocent.

Returning from Walker River to Virginia City and Carson, on the 25th I left the latter for Lone Pine, in Inyo County, California, On the 27th I reached Independence and remained two days. All the Indians in Owen's River Valley belong to the Piute nation distinctly, though there never was any solidarity or community of feeling in this nation, and the different sections or tribes were sometimes at bitter feud with each other. They have the same general habits as the Piutes of Walker and Pyramid Lakes, but are perhaps somewhat lower in the scale of intelligence and morality. In the case of the Washoes we have a tribe who have crossed the summit of the Sierra Nevada, migrating eastward; but here we find that the Piutes of Inyo County, locally called Monos, (or by the California Indians Monáchees,) have crossed the sierra in the opposite direction, and pushed their invasion of California nearly down to the edge of the great San Joaquin plains.

Among the articles composing their food-supply are the edible worms or larvæ found on the shores of Owen's Lake, and which spring from the eggs of a fly belonging to the genus *Ephydra*, but whose species does not seem to have been yet determined. Some are eaten raw, and are of a rank and oleaginous taste; others are made into soup. Among other things it is said that these Indians formerly ate a kind of mush or panada made from the seeds of the jimson weed, (*Datura meteloides*,) from which the poison was extracted by long steaming under ground. They also ate snakes of different kinds. The reptile was, while yet alive, impaled lengthwise on a stick and held writhing over the fire until broiled.

I collected here a few fragments of pottery made by a prehistoric race; and there are several inscriptions at different points from Bishop Creek to Owen's Lake, and in the cañons east of this lake, reaching within 15 miles of Death Valley, perhaps half a dozen in number, and some of them scattered along several miles on the cañon walls. I got a copy of one of them, and Dr. O. Loew, of Lieutenant Wheeler's party, showed me another, in which he thinks he has detected five Chinese characters. In my copy, however, there was nothing of this sort. These inscriptions are said to be largely geographical, depicting rivers, mountains, cañons, &c.

After a couple of days in Lone Pine, I left, on the 30th, for Bakersfield, where I arrived November 1st. After a delay of two days, I proceeded to Tule River reservation, reaching it November 4th. I found this reserve in charge of Rev. J. B. Vosburgh, of the Methodist Church, and on it about 300 Indians, classified as Tules, Tejons, and Manaches, (Monáchees.) The two first named, as revealed by their language, are substantially the same; the third (of whom I believe there are now none on the reservation) belong to the Piutes. The Tules, living along Tule River, cannot be said to have any general name. Every village has its special designation. The Tejons, living at Fort Tejon, have also a number of villages or camps, but are known as Tínnlinie, (Coyote Holes, the name of the locality.) All the Indians from Fresno River to Fort Tejon speak substantially the same language, and are one nation, so far as one can use the word among the California Indians; but they have no solidarity whatever, and, for lack of a comprehensive name, I shall call them "Yokuts"—a word which denotes people or Indians.

The tribes on King's River construct a peculiar kind of lodge. It is made of tule in the shape of a tent, with two sides to the roof and two gable-ends, and a number of them are set along in a row, side to side, and a continuous awning of brushwood is built along the front. The captain of the band occupies one end lodge, and the medicine-man the other. This sort of a village at a distance bears a striking resemblance to a military encampment. This is only where tule is plenty. In the mountains the conical hut of poles or the thatched willow-pole lodge is found.

Acorns constitute the principal staple of their vegetable food. They are gathered in autumn in large quantities and cached on the spot, or in the vicinity of their dwellings in granaries made of wicker-work about the size and shape of a hogshead, and thatched with grass or tule. These are set in the forks of a tree or on forked stakes planted in the ground, so as to be above the reach of rodents and other animals. Salmon are caught in the Fresno and San Joaquin with a number of different nets, weirs, bone-spears, &c. A booth is sometimes built over the water and closely roofed in with brushwood so as to be dark, and the fisherman, lying on his face and peering down through a hole, readily sees the fish passing beneath and transfixes it with a spear. In King's River, and in the other streams making into Tulare Lake as well as in the lake, were caught lake-trout, chubs, and suckers. Sometimes in catching fish in a running stream, the fisherman takes a kind of basket-trap in his mouth, and silently floating down the current, catches the fish as they ascend. On the lakes and sloughs, and on lower Kern River, they employed a species of canoe made of tule, with flat triangular bottom and flat sides, with a sharp prow, and about 10 feet long. Their original clothing is almost totally disused, and specimens of it are now difficult to obtain; but it was exceedingly scanty, and consisted chiefly of breech-cloths for both sexes, with hareskin robes for winter-wear or for bedding. In summer the men and children went quite naked.

These Indians have been subject for many years to the influence of the Spanish missions on the coast, and they have acquired from the Mexicans all the arts and tricks of horsemanship, while many of them are skillful *vaqueros*. The men have learned to make fancy bridles and whips of horse-hair—girdles, sashes, and the like; and the women execute very beautiful embroidery for shirts and feminine garments; and they look with contempt on some of the coarse annuity goods which are distributed among them. They are housed far better than the Indians of any other California or Nevada reservation, in comfortable, though ill-lighted, structures of adobe, and they have clean-swept floors, clean bedding, with bedsteads to keep them off the ground, plenty of clothing for the climate, and apparently enough to eat. If the reservation belonged to the Government (it is leased) so that it could have, as it has not now, control of the irrigating appliances, these Indians would be very well established; but as it is, they feel restless and uncertain, and do not make as good "improvements" as they would if they felt more sure of their future.

With the industries they have acquired also some of the vices of the Mexicans, and murders are much too frequent on the reservation; the Indians are fond of horse-racing, gambling, and drinking; and in this they are encouraged by bad men in the vicinity, who sell them liquor. Indeed, the sentiment of the whole community is hostile to the reservation rather than otherwise, so that the agent cannot procure conviction and punishment for this offense.

Leaving this reservation on the 8th of November, I went to San Francisco, where I was unavoidably delayed until the 17th. Thence I went to Ukiah City, Mendocino County, and proceeded on to Round Valley reservation, which is under the control of Rev. J. L. Burchard, of the Methodist Church. It is at present inhabited by about 950 Indians. Mr. Burchard, I am happy to state, is a very efficient officer, has a pretty thorough comprehension of the aboriginal nature, and has accomplished reforms and improvements which are quite remarkable. I visited this reservation something like four years ago, and am consequently enabled to make comparisons and state progress; and I can say that the latter has been very creditable, especially in the department of manners and morals. Mr. Burchard has thoroughly eradicated that most universal and persistent of all savage vices—gambling;

by the removal of the garrison, and by his vigorous measures in forbidding the women from visiting town, and bad whites from coming on the reservation, he has greatly abated social vice and the consequent disease; all plural wives have been put away, and most of the Indians have been married by the forms of the church; no profane language is heard, the Sabbath is well observed, and stealing is much less frequent. A church is organized, numbering about 130 members, who are regarded as intelligent and sincere Christians; there are frequent prayer-meetings and Sunday schools, in which the Indians take an active part; there are five men licensed to exhort. The whole reservation has been consolidated into a little confederacy, with a form at least of independent government; the chiefs of the tribes constitute a senate, and two delegates from each tribe make up a house of representatives—both together being "the congress of the Round Valley United States Indian reservation." They meet about once a month, and listen to the reading of, and vote upon, laws for the regulation of their every-day affairs. There is an Indian judge, who hears and summarily disposes of all cases brought before him; also an Indian marshal, who makes arrests and imprisons the culprits according to the findings and sentence of the judge. The Indians take considerable interest in all these proceedings; but whether they would long maintain the church, the Sunday-school, and the "congress," if left to themselves, may well be questioned. Their material condition is not so good as their moral and spiritual. There are very few lumber cabins on the reserve, although the Government owns a saw-mill on it. The majority of them still sleep on the ground, and you will frequently see a good bedstead shoved aside, and and the perverse old aborigine making his bed on the earth, as his ancestors did before him. They have not been taught to make floors and chimneys to any considerable extent. Most of the rancherias are built on low ground in the valley, and one at least on an old Indian burying-ground, so that the exhalations are unhealthy and productive of disease. In their native state the Indians, though there was a large population in the valley, always placed their lodges around the edge of it, on the first little bench of the foot-hills, where the atmosphere is salubrious. They would build there now, if it were made convenient for them to do so.

The long-standing differences with the settlers in the vicinity, and the consequent restriction of the area of the reservation, have not a little impaired its usefulness and unsettled the minds of the Indians. They have long been looking forward to the time when they should receive land in severalty, whereon they could build their own houses, cultivate a few acres, keep some stock, and live a somewhat independent and assured life like white men. "Hope deferred maketh the heart sick." The Indians are unable to comprehend the intricate and complicated processes of government; and they do not understand, when they were promised land so long ago, why the Great Father does not take it away from the citizens and give it to them; and they are weary and sick of hearing promises which are never fulfilled. Nothing but the strong influence of Agent Burchard over them, and the faith and courage of the more intelligent among them, have succeeded in preventing outbreaks and collisions between the Indians and the trespassing settlers.

Leaving this reservation December 6th, I returned to Ukiah City, and remained until the 11th.

All the Indians of Russian River Valley may be grouped into one nation and called the Pomos, being closely related in language; but they are, as usual, divided into a great number of petty bands and villages. For the most part they construct a lodge of willow poles, set in the ground and bent over, forming an immense round or elliptical frame, which is covered with thatch. It is often large enough to contain several families, who dwell together in the patriarchal fashion. These huts are abandoned in the spring, when the inhabitants betake themselves to open wickiups for the dry season; in the fall, when they return, they burn down these last year's structures and erect new ones on the ashes. This is their way of cleaning house. In the summer they live right among the willows where the shade is thickest, often with nothing but a few pieces of brushwood tied overhead. On the coast, where the redwood is found, a common style of wigwam is conical-shaped, and composed entirely of enormous slabs of redwood bark. They use about the same articles of aboriginal food as the Tules and Tejons above described, acorns and salmon constituting the staples.

Russian River Valley, the most beautiful and picturesque in the State, once contained a dense population, as is evinced by the ruins of ancient towns and by the testimony of the earliest pioneers. The old Indian town of Sanél, situated near the American town of the same name, once contained, judging by the regular streets laid out at right angles, and the numerous assembly halls which are indicated by the large circular embankments, 1,500 inhabitants. In 1847 it still numbered about 500 souls, though it had been subjected already several years to the proselyting raids of the Spaniards. But now they are reduced to a wretched remnant, and some tribes are nearly or quite extinct. Occasionally a ranchman has twenty or thirty "bound" to him under the laws of the State, and they live on his ranch in a state of dependence, doing occasional small services, forming a reserve force for the neighborhood exigencies in harvest, and receiving cast-off clothing and remnants of unserviceable or unmarketable food from the ranchman's granaries and cellar. He allows them to cultivate a small patch of land by the side of the stream, where it can easily be irrigated, on which they produce squashes, watermelons, and a little corn. Two of the staple crops of Russian River Valley are hops and potatoes, and in the season of harvest of these two products hundreds of Indians, old and young, get remunerative employment on the ranches. Farmers sometimes send long distances to Round Valley reservation, and apply to the agent for a score or more of Indians for this purpose; and a short leave of absence is granted them, if not inconsistent with the interests of the reserve.

Returning to San Francisco, I was again delayed a few days, and left the city on the 18th of December for Hoopa Valley reservation, via Sacramento and Redding, at that time the quickest route. I reached the reservation, after some hardships, December 24th, and remained only two days. This reservation contains about 700 Indians, and is in charge of Rev. J. L. Broaddus, of the Methodist Church. This is the number of Indians belonging here, but more than one-third of them were in the mountains, frightened away by the rumor that they were to be removed forcibly from this reservation, and transferred to Round Valley.

The majority of the Indians here are Hoopas; most of the remainder are called Redwoods, and are closely related to the former in language and customs. Both these and the two tribes on the Klamath River, as well as some others in Northern California, seem to belong to the Athabascan races rather than to the California Indians. They are a much finer people than the latter, lighter in color, faces more oval, cheek-bones not so broad and prominent. A very interesting discovery is that the Hoopa language is very closely related to the Navajo of New Mexico. There is very little doubt that the vigorous and warlike tribes of Arizona, Nevada and Oregon migrated southward from some unknown source in the North, and on the great Shasta plains on the north of Mount Shasta, encountered, centuries ago, tribes belonging properly to those known to-day as the California Indians, whom they eventually drove out to the south of the great mountain or else exterminated. This is not the place for giving in detail the facts which sustain this conjecture. At the time when the gold-hunters arrived in the country, this southward migration was still going slowly forward, the more vigorous northern race beating back the southern; and the Wylackies, the vanguard of the migration, had nearly reached the headwaters of Eel River, having, within the American period, displaced a tribe on Mad River, and driven them as homeless vagabonds over into the Sacramento Valley. Consequently we find among the Hoopas and the Klamath River tribes evidences of a northern origin. They excavate inside of their house a cellar or pit four or five feet deep which points to a long occupation by their progenitors of a much more rigorous climate than the Californian. The sweat-house (used also as a club-house and assembly-hall) is wholly underground. They are better hunters and bolder watermen than their southern neighbors; their women are more virtuous; their men less generous and hospitable, and more avaricious.

The arable land on this reservation (about 700 acres) is barely sufficient in extent for the maintenance of its present inhabitants, and as it has to be cropped every year without intermission, to do this, the soil is steadily deteriorating, and a few years more must witness its total exhaustion, when the Indians will have to be dispersed. Ill management by previous agents has dissipated a considerable part of the resources of the reservation. The herds have been sacrificed, the soil has been depleted, and the Indians who ever think of the future behold the approach of the time when they must disperse to the mountains, or submit to eviction, or be exterminated. The first of these alternatives would not be wholly unwelcome to them; but a great majority of them would choose war, and would wage it relentlessly rather than submit to the second. The citizens of this region know this well, and they are unalterably opposed to any attempts at removal of the Indians. There is a vast reserve of salmon-fishing grounds on the Klamath and Trinity Rivers, as well as acorn-bearing forests along their banks, which will not for years, if ever, be occupied by the whites to anything near their capacity for sustaining population; which are so useless for civilized dwellers, and so congenial and productive to savages, that it would be a pity ever to remove either the Klamaths or the Hoopas to any other region. All the Indians in the upper half of California could be healthfully lodged and bountifully fed along the Klamath River, and that almost wholly on the aboriginal products.

I returned to San Francisco January 7th, 1876, and was detained there until the 20th, at which time I was enabled to start for home.

I will conclude this itinerary with a few words on the California Indians in general. Physically considered, they are superior to the Chinese, at least to those brought over to America. There is no better proof of this than the wages they receive for labor, for in a free open market like ours a thing will always eventually bring what it is worth. Chinamen on the railroad receive $1 a day and board themselves; Indians working in gangs on public roads receive 75 cents a day, sometimes $1, and their board—the whole equal to $1.25 or $1.50. But on the northern ranches the Indian has $1.50 to $2 a day and his board, or $1 a day when employed by the year. Farmers trust Indians with valuable teams and complicated agricultural machinery far more than they do the Chinese. The Indian endures the hot and heavy work of the ranch better than even the Canton Chinaman, who comes from a hot climate, but wants an umbrella over his head. In a fight between the Chinaman and the Indian, the Indian will always be the victor.

The Valley Indians are more willing to labor and are more moral than the Mountain Indians, because the latter have better opportunities to hunt game and can pick up small change and old clothes about the mining camps.

An erroneous impression generally prevails as to the physique of the California Indians, because the Americans have seen only the wretched remnants of the race, the inferior lowlanders, whereas the nobler and more valorous mountaineers were early cut off. Old pioneers, especially on the upper waters of the Trinity and the higher foothills of the Sierra, have frequently spoken with enthusiasm of giants they had seen in early days, weighing 180, 200, and even 250 pounds; tall, fine fellows, not gross, but sinewy, magnificent specimens of free and fighting savagery. On the other hand, the desiccation of body in old age, especially in the women, is something phenomenal. In a wigwam near Temecula I have seen an aged man who certainly would not have weighed over 50 pounds, so extraordinarily was he wasted and shrunken; many others have nearly equaled him. This fact accounts for the repulsively wrinkled appearance of the aged, that which has made them so odious in the eye of superficial writers and fastidious tourists. There is probably no other race so excessively fat in youth, and so wrinkled in old age.

The California Indians are rapidly wasting away, and all, except perhaps a few of the Mission Indians, are practically beggars and vagabonds on the face of the earth. They are not gypsies at all, for they are attached to the place of their birth, and never willingly leave it except for a brief period. By a great majority of the people they are looked upon as cumberers of the ground. They are allowed camping-grounds, it is true, but these are grudgingly given. The great ranchers of the plains permit them to glean wheat in their harvest-fields; but in the mountains, where the farmers are poorer, they frequently forbid them even from gathering the acorns which are their staff of life. The general sentiment toward them is one of pity, mixed with one of impatient tolerance or open disgust; they are felt to be in the way. They ought to be all gathered on the reservations, where they could be thoroughly segregated from the whites and kindly cared for. It does not come within my province to make recommendations as to the locality of these reservations, or the best manner of collecting the Indians or providing for them after collected; but if it should be desired, I could give decided opinions on these questions.

INDIAN FORTS AND DWELLINGS.

By Dr. W. E. Doyle.

When in 1869 the present site of Fort Sill, Indian Territory, was selected by Generals Sheridan, Hazen, and Grierson as the best location for a military establishment in all this section, it was found occupied by a number of earthworks of a circular form and about forty feet in diameter. These were at once conjectured to be the remains of the village last occupied by the Wichitas before they left the mountains which bear their names. General R. B. Marcy, who explored the Red River of Louisiana in 1852, says of this abandoned village of the Wichitas: "Here they lived and planted corn for several years, and they have exhibited much taste and judgment in the selection of the site for their town. It is situated at the eastern extremity of the mountains, upon a plateau directly along the south bank of the creek, and elevated about one hundred feet above it, commanding an extended view of the country towards the north, south, and east. From its commanding position it is well secured against surprise, and is by nature altogether one of the most defensible places I have seen."

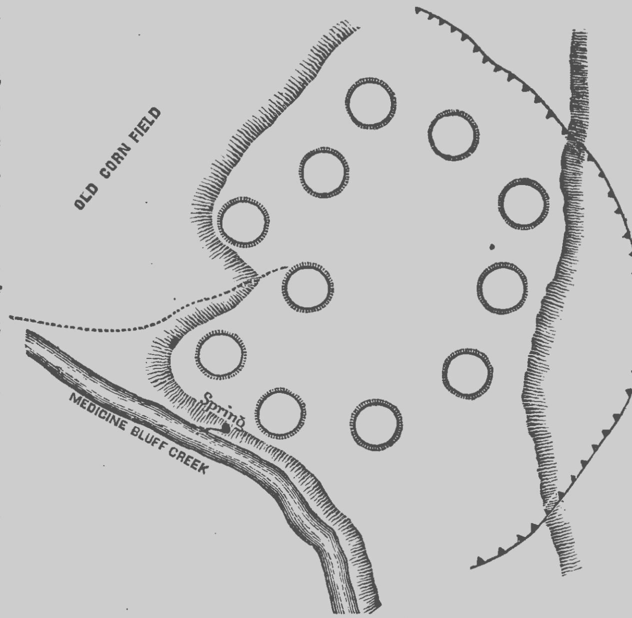
When the lines of Fort Sill were being laid out in 1869, some officers of the command were discussing the capacity of the Indian for constructing defenses, and to settle the question a sketch of the works was made. It was found upon examination that no better disposition of the earthworks, for purposes of defense, could have been made by the most skillful military engineer. Es-sad-dowa, the old chief of the Wichitas, had previously informed me that each of these earthworks surrounded one of the peculiarly constructed grass houses of that people, and that at this town a big battle was fought with the Pawnees thirty years ago. He said arrows would not penetrate the woven walls of the houses, unless shot at close range, and they were almost bullet-proof; but when this village was built only a few of the Indians of that section had guns, and it was therefore built as a defense against assailants armed with bows and arrows, lances, and tomahawks. The interior of these circular works appeared to be about a foot and a half lower than the level of the plateau, but Es-sad-dowa informed me that originally the depression was three feet. The bank which surrounded the depression seemed to vary from a foot to a foot and a half in height, but he assured me that it was originally about two feet; this would make about five feet of earthen protection for the defenders of the house, as shown in Figure 1.

Figure 1.

He further said that the houses were all wet on the approach of an enemy in order to prevent the thatch being fired by brands attached to arrows. The women and children were protected, also, by the embankment. Es-sad-dowa stated that this mode of constructing houses for defense was known to the Wichitas from their earliest traditions, and that this town was probably the last of the kind that would be built, as they were originally designed to answer the wants of a people who had no horses. "Now," said he, "what could we do with our horses (they have large herds) in places like this? The people who came to fight us would come mounted. We could not keep our horses in our houses, and if we sent them off with a small party they might be overtaken and captured. It would be better to abandon the town. lead the horses up a cañon in the mountains, and defend the entrance, When the Pawnees came we had to send our horses off to the Comanches, all but one or two in each house for the survivors to escape on, if defeated, and to follow up and observe the enemy if he retreated." These are nearly his words as I translated them. The Pawnees were defeated, and some of their bones and a skull perforated by arrows were found in 1870 by officers of the Tenth Cavalry.

By referring to Figure 2 the advantage of the disposition of the forts will be seen. The bank along Medicine Bluff Creek is about 100 feet high, that over the bottom where the corn-fields were located is about 80 feet, and that on the opposite side of the plateau about 60 feet. A path comes up the short hollow from the corn-fields, and there is a spring below the high creek bank. A naked bar extends on the opposite side of the creek. The corn-caches are in the center of the villages. According to Es-sad-dowa the Pawnees, to the number of 500, attacked them in the manner shown by the line with dots. This enabled every fort to fire and cross-fire on their line, and as there were about 400 men, women, and children in the forts, and as about 275 of this number could handle the bow and were firing on the line, the Pawnees, after getting inside the town, and unable to penetrate any of the houses, were repulsed with considerable loss.

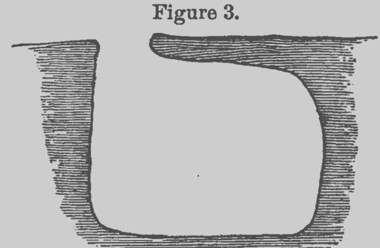
Figure 2.



Fortified camp of the Wichitas.

The Pawnee tribe, of which the Wichita is an off-shoot, formlery constructed houses nearly similar to those above described and also subterranean habitations. Of the latter, Col. A. G. Boone, the veteran frontiersman, told me that in 1825, when going to the Rocky Mountains with Ashley's trapping party, they came across quite a large village of Pawnees on the Platte. He described the houses as being about eight feet in diameter, neatly lined with grass and buffalo robes, and each forming the habitation of a family. He made a section view of one of them, as shown in Figure 3.

Figure 3.



The Comanches say that the Kiowas formerly lived in holes in the ground. It was the ordinary custom of all the Mississippi Valley tribes, when small parties were caught away from their villages by their enemies, to dig holes, in which to protect and defend their women, &c. All the early French and English writers tell of this custom, and Lewis and Clarke, Pike, and Long, all speak of it.

Lieutenant Pike thus describes the Pawnee houses in 1806. "First, there is an excavation of a circular form made in the ground about 4 feet deep and 60 feet diameter, when there is a row of posts about 5 feet high, with crotches at the top, set firmly in all around, and horizontal poles laid from one to an other. There is within this inclosure a row of posts ten feet in height forming a circle about 10 feet in diameter. The crotches of these are so directed that horizontal poles are also laid from one to another; long poles are then laid slanting, like rafters from the lower poles over the upper, and meeting nearly at the top, leaving only a small aperture for the smoke of the fire to pass out, which is made on the ground in the middle of the lodge. There are then a number of small poles put up around the outer circle so as to form a wall, and wicker-work run through the whole. The roof is then thatched with grass and earth is thrown up against the wall until a bank is made to the eaves of the thatch, and that is also covered with earth one or two feet thick, and rendered so tight as entirely to exclude any storm whatsoever and make them extremely warm. The entrance is about 6 feet wide, with walls on each side, and roofed like our houses in shape, but of the same materials as the main building. Inside them are numerous little apartments, constructed of wicker-work, against the wall, with small doors; they have a great appearance of neatness, and in them the members of the family sleep and have their little deposits." At the time Pike gave the above description, (1806,) the Pawnees were in three villages: the Grand Village, (3,130 souls,) on the Platte; Republican Village, on Republican Fork of Kansas, (1,618 souls;) Pawnee Loups, on Loup Fork, 1,485 souls, (the latter on the late Pawnee reserve.) This latter is the village Professor Hayden saw in 1867 and believed to be of great antiquity. It was abandoned at the time when the small-pox scourged the Pawnees so terribly.

I have found stone arrow-points, lance-heads, skin-dressers, &c., at numerous points through the Indian Territory, Northern Texas, and Kansas. The stone skin-dresser is still used by all the tribes who dress buffalo robes, &c., and is of the same style as those found all through the West. Hayden says he has been unable to learn from the Indians how far back they used stone arrow-points; that those he asked would point toward heaven and say, "The Great Spirit only knows; we don't." I have failed to find a single one of the tribes west of the Mississippi among whom there are not traditions regarding the stone arrowheads. Ten Bears, the old (Yamparica) Comanche chief, told me that he used them. Nemmuro, a young Comanche, showed me in 1870 the place at the west end of the Wichita Mountains where he said his father and grandfather and other Penatechkas obtained stone for arrow and lance heads. At this place, and in fact all through the Wichita Mountains, there is plenty of white quartz and jasper. Col. A. G. Boone and Jim Bridger have told me that all the Indians in the mountains and the southwestern Indians—that is, Shoshones, Utes, Apaches, Navajoes, &c.—had nothing but stone-pointed weapons as late as 1830. The Mexicans had made it a rule not to sell fire-arms to the Indians; so while the Upper Missouri Indians were well supplied with arms by the traders of the British Northwest Company and the Lower Missouri Indians by the American traders, the southwestern tribes were but poorly supplied with fire-arms as late as the above-mentioned date.

In the report of Don José Cortez, of the Spanish Royal Engineers, to the King, made in 1799, he says: "The Comanche nation is doubtless the most numerous of the many people that are known to exist in the vicinity of our most distant provinces of North America. They are commanded by a general and a lieutenant-general, chosen from among themselves, with the consent of the governor of New Mexico and the approval of the commandante of the internal provinces. These Indians are intrepid in war, bold in their enterprises, and impetuous in action. They are at peace with no other people than the Spaniards, and maintain a constant war with all the other neighboring nations." I once made a statement of these facts to Mah-wey, (Shaking-hand,) chief of the Castcha-techka (Buffalo-eater) band, and asked him how it was that the Comanches were so reduced in numbers. He explained it by saying that their enemies, especially the Osages, Pawnees, and Sioux, all had fire-arms, and cut them down in every encounter, and that when the Shawnees, Delawares, Kickapoos, Chickasaws, &c., all well armed, got into their neighborhood, they worsted them in nearly every encounter. He said the only successes they could gain would be by charging mounted.

The tribes which followed the buffalo had generally no fixed habitations, and therefore built no mounds for burial purposes or defense. Consequently, through all the great buffalo range an absence of mounds and earthworks is noticeable. In conversations with old Indians and old trappers like Boone and Bridger, I have obtained their views regarding the capacity of the Indians of the present century for defense. Boone says they understood making works thoroughly. He cited the fact that where Osages or Kaws are caught in the buffalo range by Cheyennes, Comanches, &c., they always get into the buffalo-wallows for defense. They know that a bank makes a cover and protection; they know the value of cross-firing on an enemy, and from these observations they could easily deduce plans for defensive works. But as in the days of stone-pointed weapons the arrow would carry only about 80 to 100 yards effectively, the attacking party would only have a short charge to make, and if of superior numbers, could easily carry ordinary breastworks. For this reason the large mounds were built. From their tops the arrows would carry farther, and by having piles of stones on top they could shower them on the besieger. Furthermore, no dashing charge could be made, and the defenders would have the advantage in using their lances against assailants clambering up. He further said that he does not believe the long earthworks, the remains of which are now two and three feet high, were ever intended for defense. He said (and Bridger has told me this also) that when they first got to trapping in the Rocky Mountains, fifty years ago, they frequently came across inclosures in the valleys, sometimes covering as much as 100 acres, for capturing game. These generally had an opening of several hundred yards wide and the entrance narrowed down to a pen of three to five acres. These were used by the Shoshones, Utes, and other Indians for driving game into to kill, their short-range arrows being a poor dependence on which to obtain the deer and antelope. Boone says that during the Black Hawk War they found (in Illinois) numbers of the lines like breastwork, and it was the opinion of all the old Indian men and the frontiersmen that these works were built for the purpose of obtaining game. Unlike the Shoshone and Ute inclosures, these earthworks, had numerous openings or spaces where no breastwork was built. This was for the game to pass through to be killed by parties outside. Take, for instance, a herd of buffalo grazing in the neighborhood of one of these embankments, set as they generally are near the brow of a bluff. Each of the openings is at the head of a hollow leading down to the river bottom, (as is nearly always the case.) Men are stationed on each side of the openings with bows, and arrows, and lances. A party then gets in rear of the buffalo herd and starts it toward the work. The buffalo rush forward until checked by the embankment ahead, when they rush toward the openings and are shot and lanced as they pass out. "This," says Boone, "is the only conclusion we ever came to regarding them. They were always situated too far from the river to be considered as being constructed to defend its passage, and then Indians could climb the bluff at any other point just as well, and attack the work from the rear. Had they been intended for defense, they would have been constructed in such a shape as to be defensible on all sides."

I have never found any pottery in the section formerly inhabited by the tribes who follow the buffalo, and doubt very much whether they manufactured any. All the corn-raising Indians made and used pottery, but the nomads, living almost exclusively on flesh, used it but little, if at all. Even now, with pots and kettles within reach, meat is but rarely boiled. Broiling is their favorite way of cooking their meat, and the dried meat requires no cooking.

THE SIOUX OR DAKOTA INDIANS.

By Col. Albert G. Brackett, *U. S. Army.*

To those who take an interest in the aborigines of America, a visit to the Sioux or Dakota Indians is full of novelty. They are the most powerful tribe or nation of Indians on this continent, and have always been noted for their freedom of action, impatience under restraint, and bravery in battle. There are twelve confederate bands of the Sioux or Cut-throats, named respectively the Ogalalla, Brulé, or Ishango; Yankton; Minnecoujou or Minnecoujou; Uncpapa; Yanktonnais, Cut Heads; Santees; Tetons; Sissetons and Warpetons; and Ohanapa or Two Kettles. To this number might be added the Blackfeet of the far north, or Se-ash-ha-pa, so named from their wearing black moccasins. The most powerful of these bands is the Ogalalla, and the greatest warrior is Red Cloud, chief of this band. Sitting Bull, another renowned warrior and chief, belongs to the Uncpapa band. My personal experience is confined to the Ogalallas, though I have met Indians of several other bands of this nation. Their principal ground is in and about the Red Cloud agency in Nebraska, and along the White Earth River, a beautiful stream of water embowered with trees, and surrounded with high lands and sharp peaks.

We first hear of the Naudouisses or Naudouisioux, so called by the Chippewas, from the Jesuit Charles Raymbault, who went far to the westward in 1642. The name Naudouisioux, being too long, was changed by use to Sioux, by which name they are now known. The bands on the Mississippi, or rather those who used to reside there, called themselves Dakotas, while those of the plains now call themselves Lakotas. The Jesuit Father Raymbault did not visit them in 1642, but heard of their existence, and of their being, even then, a powerful tribe. It was not until the year 1659 that the French traders discovered their teepees or lodges. They dwelt for the most part west of the Mississippi and the Red River, and extended from the Saskatchawan in the north to the lands south of the Arkansas. They were visited by the Franciscan Father Hennepin in 1680, and by Father Joseph Marest and another Jesuit in 1687 and 1689. Father Hennepin himself suffered a short captivity among them in 1680. Being so far away their intercourse with the whites was exceedingly limited, and it was many years before much was known concerning them by the people of our country.

Captains Lewis and Clarke visited them in 1804 and in 1806, and in the history of their expedition give a very fair account of them. The names of the different bands are somewhat mixed up, and it is a difficult matter for any one to understand much about them, as I find those who speak the Dakota language perfectly, have but a vague idea of them.

As near as I have been able to ascertain the meaning of the names of the different bands, they are as follows: Ogalallas, Thin Shirts; Ishangos or Brûlés, Fire Builders; Minneconjous, Those who have a farm near the water; Yanktonnais, Arrow Shooters; Tetons, Pointed Lodges; Ohanapas, Two Kettles; and Warpetons, Tea Drinkers. Of the Ogallallas there are several small divisions, among which are the Ke-ax-as, or Cut Offs; the Waz-az-e, or Branded Ones; and the E-tach-e-cha, or Bad Faces. In former times all Sioux east and north of the Missouri River were called Santees, and those west and south were called Tetons. Of late years, of course, these names have become confused, the members of the different bands wandering off and joining other Indians, intermarrying, and forming new alliances.

In June, 1852, I visited a village of the Sioux on the Mississippi River, at the head of Lake Pepin, called Red Wing, where Wa-cou-tah, their chief, resided. The houses were permanently built of reeds and thatched on top. Another large village, called Kaposia, then existed nearly opposite Saint Paul, Minn. The Indians I saw at that time were generally small men—bare-headed, their ears ornamented with steel bobs—who would in no way bear comparison with the whites, either in stature or manliness, though said to be capable of enduring great fatigue. While fishing at Lake Calhoun in 1852, the party I was with was quite successful in catching fish, which were cooked in a Sioux lodge by a squaw. The cookery was of the most filthy and wretched kind, and it took me a long time to overcome the recollection of the horrible smell of the viands after they were cooked.

At the Red Cloud agency in Nebraska there were in June, 1876, at least eight thousand Sioux, besides fifteen hundred Cheyennes and a thousand Arapahoes. These last-named Indians may be said to be cousins of the Sioux, though their language is entirely different, and they are obliged to communicate with each other by means of signs; the sign-language being understood by many different tribes throughout America. After a great deal of care and trouble, the savages have been brought together at this place, where they are kindly cared for by the Government, and some efforts are being made to teach them farming. Just before my arrival, about a thousand Cheyennes had left for the purpose of going on the war-path, and I could hear the drum, beaten by the others, as they pounded it and sang all through the summer night, sounding weird and wild enough. There are schools for the younger members of the tribe, and a few of them appear to be advancing somewhat in the way of education. To change the whole character of an Indian's ideas requires time, and too much must not be expected from these untamed sons of the western plains, whose ancestors for hundreds of years past have hunted the buffalo. The land on which the agency is located is not well adapted to agriculture, and it is not easy to see how they are to become farmers, when they have no good farming-land to work on in order to gain a knowledge of husbandry.

All about on the hills their canvas and buffalo-skin tents or teepees stretched in every direction, some being by themselves, while others were gathered together so as to form a kind of village. The framework of the tent is made by putting up twenty or thirty lodge-poles, the upper ends crossing each other and the lower ends resting on the ground in a circular form. These poles are then covered with canvas or buffalo-skins from which the hair has been scraped off. A hole is left in the top where the poles join together, that serves as a chimney and allows the smoke to pass out, the fire being built in the center of the lodge.

Around this fire there are several compartments for the different members of the family, in which there are good beds of buffalo robes and blankets. The whole affair is very snug indeed, and is as warm and comfortable in winter as need be. A large flap serves as a door, and when this is pulled down over the doorway or opening, all is cosy within. Here the women do their cooking, and the Indians eat whenever they take a fancy, they having no particular hour for eating breakfast, dinner, or supper. In their wild state buffalo and deer meat are the principal articles of diet, but at the agencies they eat beef, corn, and flour, and are remarkably fond of tobacco, coffee, and sugar. Some of the squaws are good coffee-makers, and all of them know how to roast meat to suit themselves.

Until recently the Sioux roamed over the buffalo grounds, and in summer laid in a plentiful supply of meat for winter consumption, besides robes enough for trade and bedding for themselves and families. These robes are sometimes painted with considerable skill, showing pictures of the sun, or of the warlike achievements of individuals. The robes are divided into two kinds, the first known as split robes, which have been cut open along the back of the animal when it was skinned, and then sewed together, and the others are called whole robes, as they have been taken off entire and then dressed. On the dressed side of these robes the pictures are painted, which resemble very much the efforts which a school-boy makes with his slate and pencil. Horses and warriors in full war-gear furnish the great majority of subjects, and the boasting Dakota is able by these pictures to impress upon his people more forcibly than he could otherwise do it the exceeding courage of his exploits, and the number of women and children he has butchered in cold blood. There is no boaster and braggart on earth equal to a young Sioux warrior, and in his opinion no human being ever created can in any way compare with him. Even in the hottest weather he will strut about with his buffalo robe wrapped around him, the hair being inside and the painting outside, in order that less favored individuals may properly admire his great beauty and gain a knowledge of his wonderful prowess. Heat he does not feel, if he can properly impress spectators, and he walks or rather shuffles along the most self-satisfied of human beings.

The Sioux are armed with bows and arrows, knives, pistols, and the most improved kind of breech-loading rifles and carbines. It appears that they use the bows and arrows on ordinary occasions, but, when at war, depend on their improved fire-arms. The arrows are made of straight, hard-wood sticks, feathered at one end and pointed with sharp iron heads about 2 inches long. They can send these arrows with such force as to drive them through the body of a buffalo. Years of practice have made them very expert in the use of their bows, which are really formidable weapons in dry weather, but when the bow-string becomes damp they are not so serviceable. They all like large hunting or scalping knives, which are used for almost every purpose, and they would feel utterly lost without them. The squaws have wide belts in which these knives are worn, the belts themselves being ornamented with brass nails. This belt appears to be the badge of servitude among all classes of Indian women. Sitting Bull, a warrior of the Ogalallas, (not the great chief of that name, however,) had a long lance on which he had placed three knife-blades, and when the Indians at the agency became too unruly about the buildings he would use the lance to a good purpose. On account of his lance he was sometimes called Three Knives. He was one of the guards for the agency, and on several occasions proved to be a genuine friend to the white people. There was a guard of two Indians from each band at the agency, who acted as policemen.

The Sioux like buckskin shirts and leggings, which are ornamented with fringes of the same material. Blue blankets are much worn, and the more heavily an article of dress is adorned with beads the better it is suited to their tastes. Some of the buckskin coats are stiff with bead-work, and are really beautiful. Large silver ornaments are also worn on the necklaces, being shaped like circles, crescents, crosses, and stars. Silver beads are strung together, and frequently are of great value. These Indians do not retain the scalp-lock, but let the hair grow long all over the head, painting it with vermilion, and wrapping the long ends in mink and marten skins. Many of them wear black hats which they adorn with feathers, beads, and bright-colored bands. The moccasins are worked with beads and porcupine quills, brightly tinted, and are sometimes very beautiful. The women wear garments made of buckskin with long skirts. Their hair is allowed to fall down their backs, and the place where it is parted on the top of the head is well painted with vermilion. In painting the face, the Indian dandy exercises all his ingenuity, and daubs on lines, circles, and curves in the strangest possible manner. Bracelets, too, of brass wire are also worn on all occasions, and ear-rings add luster to their wonderful toilets. No people on earth take more pains in adorning themseves than the young Indian bucks, and the greatest pleasure they enjoy is in admiring themselves in the looking-glasses which they always carry about with them.

An Indian thinks himself only half dressed without his horse, and when he is mounted with his war-bonnet on is indeed a handsome sight. This war-bonnet is an elaborate affair, made of the feathers of the eagle fastened to long strips of red cloth, reaching from the top of the head to the wearer's heels. The feathers stand upright, adding greatly to the apparent stature of the individual. Some of the Indians have fine figures, but their features are large and heavy, and their complexions dark and coarse. The noses of all of them are large and bulbous and far from being handsome. Their eyes are black, cheek-bones high, lips thick and heavy, ears large, hair very coarse, eyebrows and beard carefully plucked out, and the skin of the face has many small indentations, like those on the skin of an orange. The hands and feet are finely shaped and small, and the limbs perfectly formed. In walking they carry their heads erect, and move along in a springy sort of a way, showing great bodily vigor and a healthy constitution. Ordinarily they are cheerful in disposition, and apparently take life easy. In council, however, they are very grave in demeanor, and move slowly, in the most dignified manner; these councils are exceedingly dear to the heart of every Indian. Wrapped in their blankets, they sit down, silently waiting with the greatest patience until it is their turn to speak, and then making use of the most flowery and picturesque language they are able to command.

So far as I have been able to find out anything in regard to the religion of the Indians, they are all what might be called Spiritualists. I questioned Sitting Bull on this point, who told me that he frequently saw the spirits of the dead on the hills round about; and all young warriors, when they go through the fasting, prior to their initiation among the braves, always see the spirits of the dead who have gone before them. I asked Sitting Bull whether he saw the spirits best in the night or in the day time. He answered that it made no difference, as he could see them as well at one time as at another. The spirits of all warriors were seen in this way, as well as those of the women; but those of very young children were taken little account of.

When an Indian dies, there is placed on the platform where the body rests, or near it, all of his arms, clothing, pipe, &c., and a good horse is generally killed and left with his remains, in order that he may be well mounted in the spirit-land. When a rich man loses a relative, as a beloved wife or favorite daughter, he sometimes, in the excess of his grief, destroys all his property, including his lodge or tent, and kills all his horses, leaving himself utterly poverty-stricken. For many days he holds no communication with any one, but sits bowed down with grief, and alone. He bears his sorrow in silence. The squaws, on the other hand, howl and make the most dismal sounds, tearing their hair, and gashing their bodies with knives. I have seen some Indians who even cut off the joints of their fingers in the excess of their grief. When Red Dog's son died in March, 1872, he sat beside the body the whole day, naked, with his flesh cut and slashed, and blood running from every wound.

Of all the bands of the Sioux, the Yanktons appear to be making the greatest progress in the way of agriculture, and are rapidly learning how to take care of themselves according to the ideas of civilized men. Whether the Indians will be happier after they become civilized is an open question. They certainly were very happy when they were at liberty to roam about as they pleased in search of the buffalo herds, and enjoyed themselves as well as any human beings could while riding over the plains, lords of the wide-stretching, grassy prairies. They acknowledged no master, and moved about from place to place through the long summer days. This is now changed. The Sioux are not allowed to go south of the Platte River to hunt the buffalo, nor are those who are near the agency allowed to leave their reservations except in small numbers. The late battles which our soldiers have had with them on the Powder, Rose Bud, and Little Big Horn Rivers were to drive them to the reservations, and make them stay there. The Ogalallas have little gardens directly along the banks of White Earth River, where they are trying to raise something; but it is in a feeble sort of a way, and if any great good is expected from their farming operations they must be taken to some place where they can have ample fields, with good plows and horses. Some of them will make good farmers, as they take an interest in farming, while others will only surrender their wild ways with their lives.

I am convinced that the number of Sioux is greater than has generally been supposed, and the strength they have been able to bring into the field against our troops has astonished every one. Thousands of warriors have been seen mounted and armed, resembling more the efforts of a well-trained army than the feeble attempt of a small nation of savages. I have been at some pains to ascertain the whole number of individuals in the Dakota nation, and find at the different agencies the following result:

Cheyenne River agency in Dakota:	
Two Kettle, Sans Arc, Minneconjou, and Blackfeet Sioux	7,586
Crow Creek, Dakota:	
Lower Yanktonnais Sioux	1,200
Lower Brûlé Sioux	1,800
Devil's Lake agency, Dakota:	
Sissetons, Warpetons, and Cut Heads	800
Flandreau agency, Dakota:	
Santee Sioux	350
Red Cloud agency, Nebraska:	
Ogalallas	9,136
Sisseton agency, Dakota:	
Sissetons and Warpetons	1,807
Spotted Tail agency, Nebraska:	
Upper Brûlés, Lower Brûlés, Northern Brûlés, and Minneconjous	9,610
Standing Rock agency, Dakota:	
Upper and Lower Yanktonnais, Uncpapa, and Blackfeet Sioux	7,322

Yankton agency, Dakota:	
Yanktons	2,000
Scattered Sioux in Dakota	3,000
Fort Peck agency, Montana:	
Yanktonnais, Santees, Sissetons, and Tetons	4,126
Santee agency, Nebraska:	
Santees	800
	49,537

Many of these Indians leave the agencies from time to time and roam about among the mountains of the Big Horn and Rosebud Ranges; others are very wild, and all efforts thus far have been unavailing to bring them to the reservations.

For a savage tribe their number is very considerable, and far greater than that of any other in the United States. As has been shown, the men are good warriors, brave and determined, and if all were combined they could make a great deal of trouble; but they do not work together, and in several instances one band has not hesitated to attack another. Their numbers are increasing, and they are much more numerous than they were thirty years ago.

The Brûlé chief Spotted Tail, or, as the Indians call him, Chan-ta-gal-is-ka, is one of the foremost men of the nation, and for several years past has been friendly to the whites. Red Cloud, or Mus-pa-a-tu-ta, is also a famous chief, and these men, with Sitting Bull, may be said to be the leading spirits of the Dakota nation. I have noticed that the Indians themselves call the Yanktonnais E-hank-to-wana, giving great emphasis to the second syllable.

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